ENVIRONMENTALLY RESPONSIVE DESIGN IN BRITISH COLONIAL ARCHITECTURE WITHIN THE MEDITERRANEAN BASIN: THE CASE OF THE PRESIDENTIAL PALACE OF CYPRUS

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ABSTRACT

The conservation of historical buildings is a highly sustainable practice. Among others this is a process of reuse and preserving cultural values and past knowledge, and understanding the evolution of history and architecture. Another sustainable aspect of historical buildings is the adaptability to local climatic and geomorphological conditions through the incorporation of various environmentally responsive design features. To achieve the sustainable conservation of historical buildings the environmental design elements need to be identified, preserved and even reinforced. This paper presents an in-depth investigation of an iconic historical building – the Presidential Palace of the Republic of Cyprus – which was constructed as the government house when Cyprus was a British colony. Incorporating local construction techniques, materials and forms alongside British architectural elements, the building under study is representative of British colonial architecture on the island. The aim of the investigation was to identify the architectural and bioclimatic elements of the building that should be preserved, restored and reinforced. Additionally, other similar local colonial buildings are presented and compared alongside the Presidential Palace, to identify typical architectural and bioclimatic elements in the colonial architecture of the island. These elements include the configuration of semi-open and open spaces, as well as construction techniques, materials, layout arrangements and building shell opening characteristics. The research incorporates findings from existing literature, as well as media, photography and governmental archives. The findings of this research may be applicable in other areas of common climatic conditions, where similar typological and constructional characteristics are to be found. These findings can assist the conservation and energy retrofit actions of historical buildings.

Keywords: environmentally responsive design, environmental conservation, historical buildings, bioclimatic elements, Eastern Mediterranean, sustainability, colonial architecture.

1 INTRODUCTION

The sustainability aspect of historical and vernacular building conservation, apart from its social and cultural perspective, is often recognized through the process of reusing existing resources or through a building's small energy footprint due to the utilization of local natural materials of low processing value. The sustainable aspect of their adaptability to the local climate and geomorphological conditions is often neglected. This adaptability is achieved through the incorporation of various environmentally responsive design features in the historic and traditional settlements. Neglecting these environmental design elements during the conservation process can result in decisions that reduce or even cancel the impact of such passive design features on the indoor environmental quality, i.e. thermal and visual comfort, indoor air quality (IAQ) etc. [1], [2]. It should be noted that the utilization and enhancement of these environmentally responsive features could have a significant impact on the energy demand of these buildings.

Despite the fact that many studies have identified and assessed the environmentally responsive features of vernacular architecture [3], [4] proving its ability to adapt to the local climate, yet similar studies on buildings of colonial architecture are very limited. Colonial

WIT Transactions on Ecology and the Environment, Vol 260, © 2022 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/SC220371

architecture worldwide may be considered part of the local and regional heritage. Unlike vernacular architecture, colonial buildings were most often designed by a specific person and they tend to incorporate specific ideas and symbols connected with the aspirations of the conquerors. British colonial architecture is an amalgam of the dominant architectural style of that time in Britain, the center of the empire, confirming the British presence and role in the area and local traditional architectural forms [5], [6]. This fusion in architectural styles was also influenced by the fact that the buildings were designed primarily by Britons and constructed by local builders [5], [6]. The choice of using local labor and materials was for time-effectiveness and cost reduction. It also presented an image of an administration that creates jobs and supports the local market, as was mentioned in some Cypriot newspapers [7].

Cyprus was one of the last colonies to be ceded to the realm in the Mediterranean. In 1878 Cyprus was leased to Britain from the Ottomans through a secret deal to support the latter against Russia. Cyprus was to be under British administration but remain an Ottoman territory and pay a yearly tribute to the Sultan, until 1914. With the Ottoman Empire siding with the Central Powers during World War I, Britain annexed Cyprus and declared it a British protectorate. In 1925 Cyprus was formally declared a Crown Colony. As in other places of the world, Cyprus colonial architecture is characterized by a mixture of styles, some imported by British and some found in local vernacular architecture [6]. Moreover, due to the small size of the colony and its uncertain status, local colonial architecture is characterized by simplicity and functionality due to the need for fast construction and low cost [6], [8].

Colonial architecture often incorporated local techniques and architectural features for climatic adaptation. The climate of Cyprus is characterized by long periods of clear skies, even during winter, intense solar radiation, high summer temperatures and moderate winters. The British administration officers had realized through living in many different areas of the world that imported architecture had often proved inappropriate [5]. Studies from different regions of the world concluded that local architectural practices through a process of adaptation and improvisation incorporated bioclimatic features of vernacular local architecture [9], [10]. The aim of this paper is to explore the environmentally responsive design aspects of colonial architecture in Cyprus through the assessment of selected colonial administrative buildings. Moreover, the study aims to identify the architectural and bioclimatic elements of the British colonial buildings on the island, which should be preserved, restored and reinforced. This is the first study to investigate the environmentally responsive design aspect of the colonial buildings of Cyprus.

2 METHODOLOGY

The research presented in this paper includes an investigation and analysis of seven colonial buildings through existing literature, media, photography and governmental archives. More specifically, an in-depth investigation of the Presidential Palace of the Republic of Cyprus, which was constructed as the Government House when Cyprus was a British colony, is presented. Through this investigation the bioclimatic elements introduced in the building design are identified. Then, six additional iconic British colonial buildings in the four major cities of the island were assessed with regards to their bioclimatic elements. This study concludes with a comparison between the seven representative buildings showing common and typical environmentally responsive architectural elements. The selection of which colonial buildings to study was based on three criteria: (a) design history – should be designed and constructed by the British colonial administration; (b) use – should accommodate government services; and (c) period of completion – before WWII. The design and supervision by British engineers minimized the contribution that local master builders or

designers may have had on the final decisions concerning building design. The accommodation of administrative services in the selected buildings addressed similar needs by the building design in all cases, i.e. same working hours, office room dimensions, lighting and ventilation need, waiting areas for the public etc. Examples housing other building uses were not included in order to homogenize the sample. Regarding the time period, it was noted that after WWII, reinforced concrete constructions, along with the Modern Movement aesthetics, gradually became predominant in Government buildings [6]. As this paper focuses on the colonial architecture characterized by eclecticism merging dominant British styles and local traditional architectural elements, buildings influenced by the Modern Movement were excluded.

3 PRESIDENTIAL PALACE (PP): A REPRESENTATIVE CASE OF TYPE

Soon after the British came to Cyprus, the Public Works Department (PWD) was created and staffed by British Engineers [8]. British administration initially focused on the accommodation of British officers, troops, and the Governor. The Presidential Palace, or Government House, as it was called during the British rule, being the house of the Governor of the colony is one of the most characteristic colonial buildings on the island, infused with symbolism and local architectural forms. The history of this building is interconnected with the history of Cyprus from the beginning of British rule until today. The building site is a small wooded hill south of the Walled city of Nicosia, with the Pediaios River grazing its western edge. The first British High Commissioner of Cyprus, Sir Garnet Wolseley, chose this location instead of a house intended for him inside the city walls, as he preferred to live outside the "indigenous city" in a segregated area [8]. The pleasant microclimatic conditions especially during summer, with unobstructed winds filtered by the vegetation, was probably another reason for his choice. The immediate need for his accommodation was answered with the request for a prefabricated Government House imported from England [8].

The house was timber framed, appropriate for tropical climates and intended as a temporary solution and this prefabricated structure remained as the Government House until 1931. The Governor, Sir Ronald Storrs, envisioning the construction of an impressive colonial building, commissioned the design to Austen St Barbe Harrison who had just designed the Government House in Jerusalem. However, in 1932 Storrs was replaced by Sir Reginald Stubbs who considered Harrison's proposal too grandiose and costly for the economy of a small colony like Cyprus. He cancelled Harrison's contract and assigned the design of the "New Government House" to Maurice Webb, of the London office "Sir Aston Webb & Son". The construction of the building began in November 1933 and was completed in the middle of 1936. The construction was under the PWD and J. V. Hamilton, an architect sent from London, was assigned to supervise the construction. Interestingly, even though Stubbs played a leading role in the building's design, he was replaced by Sir Richmond Palmer before the building was completed who then became the first resident governor.

The design of this building expresses the thinking of the times with regards to colonial architectural style. The building incorporates arcades copied from an 18th century monastery, a four-story tower which references the medieval castle of Kolossi, Byzantine and Ottoman domes, column capitals from Byzantine or Frankish buildings found in Cyprus, doors that were replicas of those to be found in ancient monasteries of the island, British glazed doors and windows, and neo-classical symmetric layout were introduced in the design [6], [7]. The amalgamation of forms located in older structures on the island, from different time periods and architectural styles, made this building an indicative example of the colonial administration intention to develop a "Cypriot" style.

The building has a U-shaped layout with building volumes around a central courtyard open toward the south. The north wing is two-story with a central four-story tower facing the courtyard and a projecting two-story central building volume of ashlar stone on the north (Fig. 1(d)). This projecting volume has an arcaded porch on the ground floor leading to the main building entrance and a room fronted by an arcade on the upper floor. The east and west wings are single-story. The two-story volume is covered by a pitched roof, while the single-story wings are covered by hipped roofs. The roof tiles are made of local clay. The layout is characterized by symmetry along a north–south axis with the imposing entrance placed at the center of the north elevation. The ground floor accommodated the Governor's office, the Council Chamber and rooms where official balls and dinners were held, while the living quarters for the family and guests were on the upper floor.

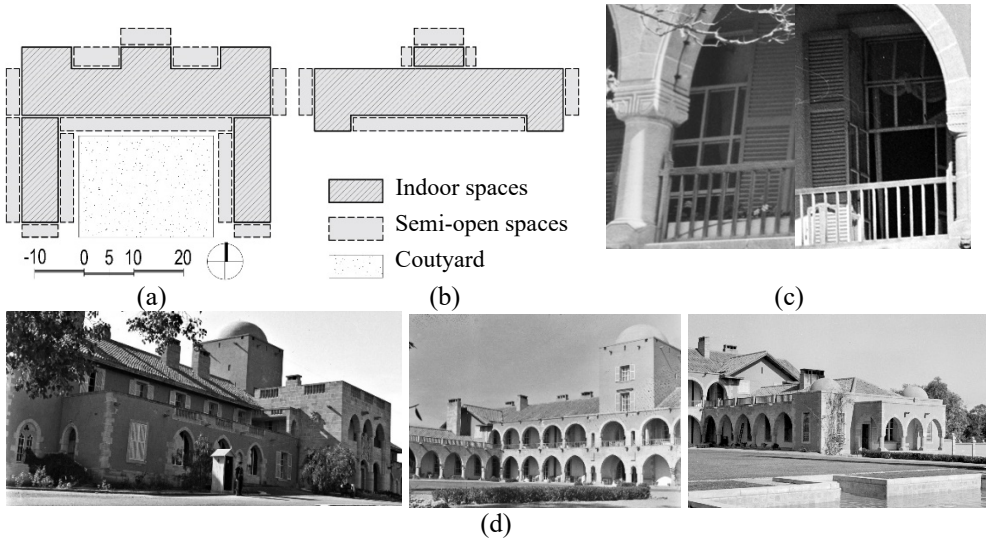


Figure 1: Government House schematic plan views. (a) Ground floor plan view; (b) First floor plan view; (c) Left: double-hang window – leaves in center position*. Right: door – top window slightly open**; and (d) Government House photographs from the 1950s*. *(Source: * PIO, Photo by Felix Yaxis; ** PIO.)*

3.1 Bioclimatic elements

The environmentally responsive design features found in the building can be classified in five categories: the materials, the cooling strategies, the heating strategies, the strategies for microclimatic regulation and the strategies to improve indoor daylighting.

Regarding building materials, the structure is of load bearing stone masonry, 50 to 60 cm thick. This massive building envelope is particularly appropriate in climates with high diurnal temperature variation such as the Mediterranean [2], [3], [11]. The building envelope absorbs and stores heat during the hours of sunshine, while at the same time ensuring the minimum thermal influence to the indoor environment. During the winter season, the thermal mass minimizes thermal losses while also acting as a heat storage element during the daytime and for heat supply during the night. Similarly, during the summer heat transfer to the indoors is delayed and the highest indoor temperatures occur with a time lag, compared to the outdoor

environment. This time lag is highly significant as the outdoor temperature decreases as time passes. If this strategy is combined with natural ventilation during nighttime, when the outdoor air is significantly cooler, the building envelope and associated spaces are thermally discharged and the same process is being repeated the following day [11]. Moreover, in the exterior the high thermal inertia of the soil keeps the temperatures lower during summer, while paved areas absorb radiant heat, thereby increasing the external temperature.

The heating strategies identified in the building are presented in this paragraph. The bioclimatic orientation is observed in the layout composition. The main living rooms are placed on the south side of the building, while the north side accommodates secondary spaces like corridors and restrooms. Moreover, on the north side of the building there are two semi-open spaces with pointed arches, one on each side of the entrance, that were converted into cloakrooms with sliding windows. South openings may increase solar gains in building interiors and ensure direct heat gains. Indirect heat gains are achieved when the massive structure absorbs solar radiation throughout the day and returns it to the interior spaces with a noticeable time lag [2], [3]. This layout composition allowed for utilization of winter solar gains and minimization of time spent in the colder north spaces.

The following paragraphs present the cooling strategies identified in the Presidential Palace. The building wings are elongated, with stone arcades located primarily around the central courtyard. The south side of the two-story wing is fronted both on the ground and on the upper floor by arcaded verandas. The south sides of the single-story wings initially did not include covered spaces. In later years, arcaded semi-open spaces were added on these sides, as shown in photographs from the 1950s (Fig. 1(d)). Even though a south orientation is beneficial during winter, during the summer different shading elements need to be added to minimize solar gains. South semi-open spaces shade the building envelope during summer, when the sun is at a higher position, while allowing direct solar radiation to reach the building during winter, when the sun is lower [2]. The west and east sides of the building wings are also mostly fronted by arcaded semi-open spaces. These spaces are also beneficial on west and east sides, especially if they are arcaded so as to minimize the solar radiation even when the sun is lower due to increased wall area. These semi-open spaces work similarly to the vernacular bioclimatic element of *iliakos* and even retain its proportions [2], [3]. Eastern semi-open spaces are not placed on the east single-story wing probably because this was the least visible side and it accommodated rooms for the staff. Moreover, no overhangs were placed on the east and west sides of the rooms located in the upper floor of the entrance building volume. In a letter dated 2 April 1937 [12], Sir Palmer, complains about the overheating of these rooms due to solar radiation and mentions the addition of verandas that did not "spoil the appearance and harmony of the façade" on the west and east sides (Fig. 1).

The building fenestration was of steel framed casement glazed doors with a top window and double-hang windows (Fig. 1(c)). The material, proportions, and opening mechanisms are of British origin as they are not found in local traditional architecture. Other bioclimatic features to be found on the building, that is also found in the vernacular architecture of the island, are the window shading devises. On the ground floor the glazed windows and doors are fitted with shading devises with the exception of the openings in the semi-open spaces. This underlines their role as devises that protect from solar radiation, but also from other weather elements such as rain or strong winds. All windows of the upper floor are fitted with shaders, probably for lighting control and privacy reasons. Shaders are also placed on the north openings. This decision offered an extra protection from the strong and cold north winds. The shaders were primarily operable, timber shutters with louvers while a few, on the more elongated windows, were timber lattices. Even though the louvers provide shading, they do not block the light completely and simultaneously allow for air circulation.

Another bioclimatic strategy identified in the building, is natural ventilation. Natural ventilation can be wind-based, entering through a window on the windward side of the building and exiting through another window on the leeward side. Thus, windows on different building sides are needed to achieve cross-ventilation. Even though many windows and doors are placed in all the external walls of the building under study, only a few rooms can benefit from cross-ventilation. This is because most rooms have openings only on one side, with an interior corridor providing room access on the opposite side. Since many openings are also placed along the corridors, cross-ventilation can be achieved through the opening of the internal doors. Natural ventilation can also be achieved through buoyancy-driven ventilation (stack effect). In the building, stack-ventilation can be achieved through the top windows or through the placement of the leaves of the double-hang window in the center position. Moreover, natural ventilation is achieved through a system of in-wall ducts where the warm foul air rises naturally and expelled to the outside environment through vents in the roof stacks. This in-wall system for improving the indoor air quality of the rooms, was imported from Britain.

The design of the roof could also have a significant impact on the indoor environment. Initially, the rooms had high ceilings allowing for better air distribution. Moreover, the roof structure was covered by the placement of a wooden ceiling. This resulted in a closed space that worked as a buffer zone between the outdoors and indoors, increasing the insulating properties of the roof. In some cases, like those at the Government House, the roof was naturally ventilated. This exfiltrated any warm air trapped in the roof and induced cooling of the roof space and its structural components. Finally, local traditional materials, such as limestone and gypsum-based plasters are used in light colors, reflecting thermal radiation and thus reducing the radiation absorbed by the building envelope. This reduces the chance of overheating during the summer.

With regards to strategies for improving microclimatic regulation, one of the most common elements found in vernacular architecture in Cyprus is the courtyard [3]. The Government House, as mentioned above, is placed around a central courtyard open to the south. The courtyard is covered with grass, shrubs and a few trees. The solar gains noted at the courtyard are reduced, while if combined with vegetation, the microclimatic conditions are highly improved. More shading is provided to the building and the courtyard floor thereby reducing temperatures. The thermal mass of the surrounding surfaces also moderates temperatures during summer and winter, while vegetation moderates the humidity level, dust and other weather elements. The south orientation of the courtyard allows for south, east and west oriented spaces looking towards the courtyard. The overlook towards the courtyard, a private area of the building, allows for an increased number of openings permitting high levels of indoor daylighting and natural ventilation. Moreover, the improved microclimate also effects the indoor spaces in a positive way.

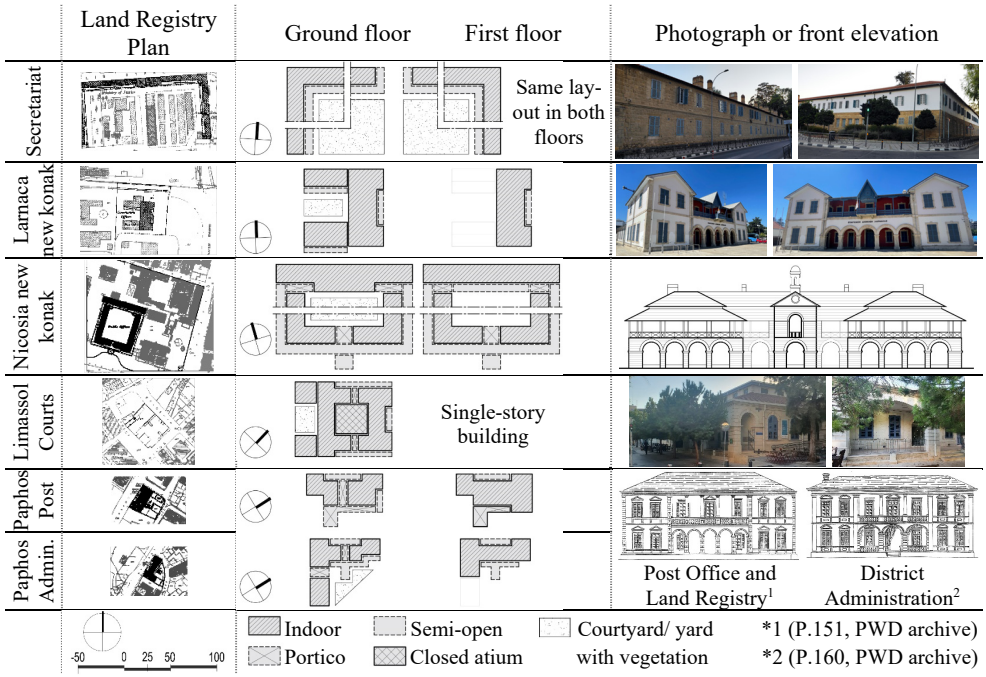
Finally, based on the building's design high levels of natural lighting reach the indoor spaces through a significant number of glazed openings. Moreover, the openings are very high and they incorporate top windows. Vernacular architecture often underperforms in daylighting levels, as cultural and construction restrictions resulted in fewer and smaller openings. During the British rule this changed and high windows were incorporated overlooking all directions, with much more importance placed on building façade composition towards public roads. The need for high daylighting levels is expressed by Palmer who requested the extension of the east and west halls through the incorporation of ground floor east and west verandas [12]. The purpose of this modification was for increasing the room area and for the benefit of the natural lighting of these spaces, which opened solely on the east and west sides.

4 DESCRIPTION OF SELECTED COLONIAL BUILDINGS

This section presents the analysis of six colonial buildings in Cyprus, other than the Government House. The Secretariat and the "new" Konak in Nicosia, the "new" Konak in Larnaca, the Limassol Law Courts, the Paphos Post Office and Land Registry building and, finally, the Paphos District Administration building. These buildings located in the four major cities of the island were constructed from 1882 to 1937. District Administration buildings were called "Konaks" during the Ottoman period, thus many of the buildings under study were known as "New Konaks". The analysis includes a brief presentation of each building's history, typology, site location and building layout. The analysis also includes the identification of the building's environmental passive design strategies.

Many architectural and bioclimatic design features are common in all case studies. They are single or two-story, stone-built structures with inclined roofs. All colonial buildings are made of similar materials, specifically load-bearing, thick, stone-made walls. The indoor spaces have high ceilings and the roof is always pitched and covered with local clay tiles. In some cases, the roof is hipped and in others is gabled but always sealed with a wooden ceiling. Finally, the fenestration is always fitted with external operable timber louvered shutters. In some cases, the louvers are adjustable allowing the building occupant to adjust the rotating angle of the louvers.

Table 1: Positioning in site, floor layouts and views of the buildings under study.



4.1 Secretariat Building, Nicosia (Sec.)

The Secretariat is the first permanent building to be constructed in Cyprus by the British administration [6]. The building was designed by the Government Engineer William Williams in 1880 as barracks to accommodate the "Cyprus Pioneer Corps". It is located in a

large plot of land on the Southwest of the old city of Nicosia, on the way from the city to the Government House. The building layout is U-shaped enclosing a parade ground. More specifically, the U shape results from two mirrored L-shaped two-story wings. The small distance between the two wings creates a northern entrance way to the central yard. The internal area of the building is about 2,400 m^2 making it the largest of the buildings under study. The construction took place between 1880 and 1882 and it was completed in phases. The west L-shaped wing was the first to be constructed [6]. Before the completion of the building the "Cyprus Pioneer Corps" was disbanded. Consequently, it was decided that the newly build construction was to be adapted to accommodate colonial administration uses like the Secretariat offices, the Treasury and the Government Engineer's Department, the predecessor of the PWD [8]. The architectural design is simple, well-proportioned and focusing on function and environmental acclimatization.

With regards to the bioclimatic design strategies, the orientation of the building layout is clear with the building blocks positioned on the North, East and West sides of the central yard leaving the South side open. The central yard cannot be considered as a courtyard with regards to bioclimatic behavior, as due to its great size any effect of the surrounding volumes on the microclimate of the yard is diminished. The building consists primarily of ashlar load-bearing, stone-made walls. Probably due to lack of funds, the upper floor of the north-eastern side of the building was made of lightweight timber-framed construction with stone rubble infill and gypsum plaster rendering. The building blocks are two-story and consist of rows of shallow depth rooms with semi-open spaces at the side of the yard, southward, westward and eastward and they were used both for building circulation and for sun protection. The semi open spaces of the ground floor are pointed arch cloisters and on the upper floor they are lightweight verandas with timber posts supporting the roof. The arches increase the wall area providing more shade while the roof of the upper veranda is fairly low to minimize the direct sunlight that reaches the rooms. Additionally, the architectural element of in-wall ventilation is introduced in this building. In this case, the system includes a fresh air inlet on the exterior wall near the ceiling with perforated terracotta or cast-iron grilles on the outside and adjustable timber louvers on the inside. At the same time, foul air is exfiltrated through an internal opening with louvers near the ceiling connected to terracotta pipes located within the interior wall. The warm foul air rises naturally through the pipes and is expelled to the outside environment through the openings of a ventilation stack [8].

4.2 "New Konak" of Larnaca (KL)

The "New Konak" of Larnaca accommodated District Administration, the Land Registry and the Post Office. It has a U-shaped layout formed by a two-story east wing and two single-story wings on its north and south sides. The two-story wing was built in 1882, along with the harbor works, by the Government Engineer Samuel Brown. The other two wings were added in 1915 by the PWD [6], [8]. The north side of the ground floor was occupied by the Land Registry offices, while the south side was occupied by the Post Office. The District Administration offices were located on the upper floor. The architectural design of the building is very characteristic of British colonial architecture as it follows a pattern for public buildings developed in other British colonies as well [6]. Specifically, the building's main façade is a composition of two gabled building volumes, one at each end, and a central building volume with a porch of semi-circular stone arches on the ground floor and a lightweight colonnade of timber posts on the upper floor. The symmetry in both the layout and the façade of the building is explicit. The staircase is in the center of the two-story wing

in an entrance area that served as a circulation distribution element towards the other rooms of the building, like a "closed portico".

As mentioned above, the building layout is U-shaped forming a central courtyard open only on one side. In this case, and in contrast to the first two buildings under study, the building volumes are on the north, east and south sides of the courtyard leaving the west side open. The orientation of the building was probably defined by of its relative position to the seafront. Nevertheless, the bioclimatic principles are clear in the decision to create covered spaces on the south of the one-story wings. Specifically, there is a semi-open arcaded space in the north building volume towards the courtyard and an iron veranda projecting southward of the south building volume. The iron veranda unfortunately no longer exists, but it can be seen in an old postcard from 1931 and it is also mentioned on the ground floor plan of the 1915 extensions [6]. In the same postcard the rich vegetation of the courtyard is also visible.

4.3 "New Konak" of Nicosia (KN)

This building was constructed in 1904 on the land where the Lusignan Palace once stood. Any proposals with a view to preserving the old Palace were denied and it was decided to construct a completely new building which would project a British image, cost less and be more functional [6], [8]. So, in 1899 Charles Bellamy, Director of PWD at the time, designed this building based on a previous scheme by William Williams. For reasons of economy stone rabble from the older demolished palace was used for the new structure. The "new" building housed the Law Courts, the Post Office, the Land Registry and the Commissioner's office.

The building layout is a quadrangle with a central courtyard covered by rich vegetation. The layout is symmetrical, especially with regards to the front façade. The building façade and side elevations are characterized by a continued stone-made arcade on the ground floor and a lightweight covered veranda on the upper floor. The arcade consists of semi-circular arches on stone piers and the upper veranda is covered by a lower separate hipped roof supported by pairs of timber posts that correspond to the piers below. To give a central focus, a two-story stone porch is projected at the center of the façade.

The bioclimatic aspect in the design of this building is explicit through the positioning of the semi-open spaces and the low-ceiling, verandas. The building façade corresponds to the south side of the courtyard, the side elevations to the east and west sides while the back of the building faces north. The south, east and west sides are clearly symmetrical, with covered open spaces on the building exterior, thereby protecting the internal spaces from intense solar radiation. This is not repeated on the interior perimeter of the courtyard, as the vegetation provides adequate protection from the east and west sun. It is interesting to observe that the layout of the north building wing differs compared to the other three. No covered space is added to the exterior side of this wing probably because it is on the north and thus does not need any solar protection. Moreover, on the south side of this wing a partly closed corridor is added on the ground floor while on the upper floor there is an open colonnade. The south side of the ground floor is fairly protected by the vegetation while the upper floor gains a south facing covered veranda. In this building we observe another bioclimatic element, the "portico", a transitional space which connects the public street with the building circulation spaces. In this case, "porticos" are found in the south main entrance to the courtyard and in the entrances from the west and east sides. Moreover, a ventilation turret with a weather vane on top is placed in the center of the south wing's main roof, thus concluding that stack ventilation strategies are incorporated to the building to exhaust foul and warm air and increase air circulation. Finally, the louvers of the window shutters are adjustable. The shutter's frame is divided in three parts by height, with horizontal louvers in each part. In the

highest part the louvers remain fixed while in the two lower parts the louvers are adjustable through central timber rods that connect and control the louvers of each section.

4.4 Limassol Law Courts (LLC)

This is another building designed by William Williams and constructed by the PWD. The construction was completed in 1911 to accommodate the District Court. The initial layout was a quadrangle with rooms around the Main Court Chamber and semi-open spaces in part of the front façade and side elevations. The single-story building has a hipped roof with a separate elevated hipped roof above the central chamber. Operable windows are placed on the walls that support the elevated roof. Some extensions and modifications took place in 1928 based on plans by Joseph Gaffiero of the PWD [6]. Two blocks were added on the rear view of the building, one on each side, forming a small courtyard. The front view is characterized by symmetry with a central arcaded porch, covered by a wave-form pediment, two identical building volumes on each porch side and two identical arcades at each building end. The arcades and porch consist of semi-circular arches on stone piers.

The building façade is orientated towards the north-east. The building was placed relative to the two vertical sides of the plot and faced the main road. Thus, the layout was highly affected by the existing public roads and the plot shape. Consequently, the semi-open spaces are to the north-east, south-east and north-west. Even though they offer protection from east and west solar radiation, the decision of their positioning, especially of the front porch, was probably defined by the public road. The extensions of Gaffiero formed a south-west courtyard that, based on old photographs [13], was covered with vegetation. Three different louvered shutters are identified in the building, two adjustable and one fixed. All the shutters' timber fames are divided in three parts height-wise, with horizontal louvers in each section. The louvers on the north side are fixed while the louvers on the side windows are adjustable. The louvers on the front of the building have a circular upper part with fixed louvers, a lower part with louvers adjusted by timber rods and a middle part that can be opened separately from the rest of the shutter, which also contains adjustable louvers. The choice for the front shaders was probably due to privacy concerns. The workers could open a smaller higher part of the shutter introducing daylight, while remaining unseen from the public road. The fixed louvers on the back were chosen either for reduced cost or because during the time of the extensions the fixed louvers were more common. Another bioclimatic element is the "portico" which corresponds to the passages from the side arcades to the central Chamber. The final bioclimatic aspect of the design is the elevated central roof with operable windows. In many old photographs [13] the windows are wide open to allow the warm air to be dissipated thereby increasing air movement and replacing the indoor air.

4.5 Paphos Post Office and Land Registry building (PPO)

On a hill overseeing the sea, Paphos Post Office and Land Registry building and Paphos District Administration building that were constructed during British rule stand close to each other along Nikodemos Mylonas street in Paphos. In 1918 the decision for the construction of a new building in the place of the "old konak" to accommodate the Post Office and the Land Registry was taken. The new building featuring a colonial style of architecture was designed by Joseph Gaffiero and was completed in 1919 [8]. The building is located on a privileged yet sloping site rather limited in size and irregular in shape. Its two building sides are along the plot limits and only the two sides along the public roads can have adequate number of openings.

This colonial building is characterized once again by an imposing symmetric façade. Two-story building volumes are placed at each end of the façade and a recessed section fronted by semi-open spaces is placed in the center. The ground floor of the central section is fronted by an arcaded porch of five semi-circular arches supported by piers and on the upper floor by a colonnade of Tuscan columns. The fenestration is freestone-framed with neo-classical pediments. The details and composition of this façade resembles a Renaissance building along with green-shade timber louvered shutters fitted on the stone-framing of the fenestration, for local distinctiveness. This symmetry is not consistent in the building layout. This was a result of the irregular shape of the site along with the influence of colonial layout design – that often introduced the element of an all-round veranda [6], [8]. On the ground floor a secondary arcaded porch was introduced at the side elevation and a portico was located at the back leading to the staircase. Due to the limits of the plot no openings could be introduced to the back wall or the side walls resulting in a long corridor open only on one side. This corridor is also connected to the front porch through a portico. On the upper floor, only the front semi-open space is repeated. The building façade is oriented towards the west-northwest while the other building side adjoining the street faces north-northeast. The semi-open spaces protect the main building mass from east and west solar radiation and create comfortable exterior-yet-covered public reception spaces. With regard to the shutters, the two thirds of the louvers are adjustable. Nevertheless, there are no south openings, limiting the bioclimatic advantages of south oriented openings, especially when this fact is combined with the high thermal mass of the building envelope. Moreover, the absence of openings on two sides of a deep layout result in some spaces that are underlit and under-ventilated. In this case, the existing street layout was a primary factor in affecting the building design, while the bioclimatic considerations were seconded.

4.6 Paphos District Administration (PDA)

The second building of this complex, housing the District Administration, was also designed by Gaffiero and was completed in 1921, soon after the Land Registry and Post Office building [6], [8]. This structure is also in a corner and sloping site, rather limited in size and with an irregular shape. However, in this case three of the plot sides are adjacent to a road while the forth faces another building plot owned, at the time, by the British administration, thereby, allowing for window openings on the fourth side of the building as well. Many similarities can be found between Paphos Post Office and Land Registry building and Paphos District Administration building designed by Gaffiero, especially with regards to their impressive façades. The architectural components of the façades and their dimensions are very similar. The ground floor central porch includes three elongated semi-oval arches supported by stone piers and the upper floor is supported by a colonnade of Tuscan columns aligned to the piers below. Another difference in the detailing is found in the window pediments which are curved rather than triangular. The site limitations affected the layout of this building too, yet more symmetry is found in this case. The layout is L-shaped, following the shape of the site. The main entrance, a central portico and the monumental staircase, which is projecting beyond the back of the building, are placed along a central axis. Through the L-shaped layout the round corner of the site encloses the yard, overlooked by the back offices. The façade of the building is oriented towards the west-northwest and the side wing towards the south-southwest, leaving the back yard open to the southeast. Additionally, semi-open spaces facing the yard are located on the ground and upper floors protecting the building from the south and east summer sunlight. The upper floor of the side wing covers only a part of the south side, in contrast to the ground floor which extends to the opposite plot limit. The lower height

of the southern wing allows more direct solar radiation to reach the building envelope during the winter, while the back semi-open spaces protect the building from overheating during the summer. Openings in the rooms ensure adequate natural light and ventilation. Again, two thirds of the louvers are adjustable using central timber rods.

5 RESULTS, DISCUSSION AND CONCLUSIONS

Environmentally responsive design in colonial architecture of Cyprus is fairly evident as all the buildings investigated incorporate at least 14 of 21 bioclimatic features identified in the study. 11 of 21 bioclimatic elements are incorporated in all the buildings under study. The features related to materiality are incorporated in all buildings. Additionally, the cooling strategies are dominant, while heating strategies are few. This can be explained by the prevalent warm climate conditions in Cyprus. With regard to the heating season, it should be mentioned that fireplaces were introduced in all buildings. The building with the most bioclimatic features is the "new" konak in Nicosia with 20 of 21 elements and second with 19 of 21 elements is the Government House. Many elements were identified in all the buildings investigated, like east-or-west-facing verandas, window shaders, cross ventilation, high thermal mass, closed pitched roof, high ceilings, light colored materials on exterior surfaces and an increased number of external openings. South openings and yard with vegetation are only absent in the case of the Paphos Post Office building, which resulted from the many limitations of the plot together with the decision to face the sea and the public road. Similarly, south facing verandas were not identified in the two buildings at Paphos. The small plots along with the orientation of the public road – as was first considered – also eliminated this feature. Nevertheless, the Paphos District Administration building still incorporates a southeast semi open space, since the south side faces another plot. The features less common, yet still to be found in more than half of the buildings that were investigated, are the "portico", adjustable louvers, central courtyard and the stack ventilation strategies. With regards to stack ventilation, unfortunately in some cases this could not be identified, nor if operable top-windows existed in the building fenestration. The least common bioclimatic features were the ventilated roof, found in two of the seven cases, and the positioning of secondary spaces to the north side of the buildings, a condition only observed in the Government House.

This study found that colonial buildings incorporate both local and imported architectural and bioclimatic elements. The elements to be found also in the local vernacular architecture are high thermal mass, semi-open spaces, cross and stack ventilation, window shaders, utilization of solar gains, courtyards and vegetation [3]. The colonial bioclimatic elements departing from vernacular architecture elements are the closed roofs with wooden ceilings, which became characteristic of urban architecture from this period, as well as the natural ventilation system served by in-wall ducts and the increased number of wide and high windows and glazed doors. This study identified and presented the common bioclimatic features of colonial architecture to be utilized by engineers during the conservation of colonial buildings in Cyprus and other areas of the Mediterranean basin where similar building types exist. Moreover, these features are part of the authenticity of these historical buildings and as such they should be identified, preserved and enhanced as they may achieve lower building energy demand. The colonial buildings have a unique character and they form a significant part of heritage architecture with many aesthetic, historic and environmental values that should be taken into serious consideration during conservation. The preservation of these buildings is very important, with benefits to the society as a whole.

Table 2: Bioclimatic features of building under study.

	Cooling strategies											Heating strategies			Micro-climate			Materials		Daylight		
	South verandas	East or west veranda	Portico	Window shaders	Adjustable louvers	Stack ventilation	Cross ventilation	Closed pitched roof	Ventilated roof	High ceiling	Light colors on walls	South openings	North secondary uses	Materials utilizing thermal sun radiation	Yard with vegetation	Courtyard	Semi-open spaces of massive structure	High thermal mass	Reduced external paving	Increased number of openings	Top window/skylight	Sum
PP	■	■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	19
Sec.	■	■		■		■	■	■		■	■	■		■	■		■	■	■	■		14
KL	■	■		■			■	■		■	■	■		■	■	■	■	■	■	■	■	16
KN	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	20
LLC		■	■	■	■	■	■	■		■	■	■		■	■	■	■	■	■	■	■	18
PPO		■	■	■	■		■	■		■	■			■			■	■	■	■	■	14
PDA	■	■	■	■	■		■	■		■	■	■		■	■		■	■	■	■	■	17
Sum	5	7	4	7	4	4	7	7	2	7	7	6	1	7	6	4	7	7	7	7	6	

ACKNOWLEDGEMENTS

This research was conducted within the framework of the cooperation project "Energy Upgrading of the Historic Buildings of the Presidential Palace of the Republic of Cyprus and Loggia – Heraklion Town Hall" with the acronym "ANAVATHMEZO". The project is co-funded by the European Union (ERDF) and national funds of Greece and Cyprus through the Interreg V-A Greece–Cyprus Cooperation Program 2014–2020.

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