Adaptive Use of Passive Shading Devices in Public Buildings: A Case of Famagusta

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Abstract

Energy efficient and sustainable design of public buildings aims to reduce the consumption of non-renewable energy resources by promoting thermally and visually comfortable spaces. Integrated shading devices as part of a passive system is desirable to the successful design of energy conserving buildings. However, limited research exists on the adaptive qualities of shading devices as employed in the public buildings of North Cyprus.

This research discusses the adaptive application of shading devices in public buildings within Famagusta, questioning the contextual use and suitability of PSDs in terms of application. To achieve this, two prominent public buildings in Famagusta (EMU Rectorate building and Lemar shopping mall) were reviewed, presenting findings from shading analysis of a comparative study.

A qualitative and quantitative research methodology was adopted for this investigation. Questionnaires were used for data collection, and for analysis, SPSS was used to obtain percentages from data collected. Findings show a 94% user discomfort with the indoor thermal levels, which corresponds to higher shading demand from the users, at the EMU Rectorate building. The Lemar building survey indicates satisfaction with the levels of indoor thermal comfort, but 86% indicate the partially shaded South-Western building parts are hardest to cool.

Keywords: Adaptive use, Passive Shading Devices (PSD), Public Buildings, Mediterranean Climate, Famagusta.

1. Introduction

The amount of sunlight admitted into a building in warm sunny climates may result in high cooling energy consumption when excessive; Southern and Western oriented windows may permit sustained sunlight which results in passive heating. In nearly all climates controlling and diffusing natural illumination will improve daylighting. The use of external shades in building facades is known to contribute to a decrease in a building's energy consumption and to improve users' visual comfort. This is achieved by controlling the level of sun radiation and daylighting on a building's exterior walls and within the building's interior (Prowler, 2008). The employment of passive building concept for attaining thermal comfort inside a building is a growing concern for the building energy protection. The fundamental principle is to provide shading devices as part of location, size and orientation to require most advantage of the surroundings and indoor thermal (Chan, Riffat et al. 2010).

Passive solar design strategies, as part of a larger solution to current sustainability issues in the world, demand an environmentally friendly and responsible approach in design. Therefore, the adaptive integration of PSDs into the design of buildings seeks to provide comfort and energy savings, thereby solving direct and indirect cost loads (Kats, 2003).

Famagusta is a fast-growing city in Northern Cyprus, an internationally un-recognized developing country which has serious environmental problems. Studies have highlighted the most important environmental problems in the country as Energy problem, Lack of planning, Water pollution, and Environmental pollution, Waste, and Soil pollution in descending order (Eminer et al, 2014). Sustainable Energy policies for the Mediterranean region demand the use of passive strategies for the heating and cooling requirements in the summer and winter periods, to reduce the use of non-renewable fossil fuels to power mechanized thermal comfort systems.

Considering the energy challenges of the region, this case study research aims to analyze the bioclimatic use of PSDs in public buildings of Famagusta, North Cyprus and to achieve this, two public buildings (Eastern Mediterranean University (EMU) Rectorate Office Building and Lemar Shopping Mall) were selected for review based on their application of PSDs. The appropriateness of shading devices employed on both cases was compared for efficiency considering factors like climate, solar orientation and energy performance.

PSDs adapted to the Mediterranean climate of Famagusta should feature deep shade that protects the glazed regions and general mass of (often expansive) public buildings from unwanted heat gains, but should be dynamic enough to admit sunlight in the cooler months.

A review of shading devices and their regional adaptive qualities is discussed contextually, with a brief examination of the climatic conditions in Famagusta. The highlight of this research presents a comparative result of the influence of various passive shading devices. It further reveals the key suitability factors and application dimensions thereof, which informs suggestions on optimal shading devices in the context.

A qualitative and quantitative research methodology was adopted for this investigation. Data collection was done by comparative analysis regarding information derived from observation, and qualitative survey by questionnaire has been carried out to assess the user perception of thermal comfort in both buildings. SPSS was used to obtain percentages from data collected and analysis performed to attain facilitate outcomes.

2. Literature Review

Through the architecture history and related cultures from classical to unrefined vernacular structures, shading has had various advantages that can be found in its applications to history (Sadler, 2005). The use of external shades in buildings influences various quantifiable and perceptual performance criteria. Among these criteria are energy consumption for heating, cooling and lighting; the amount and distribution of daylight; glare effect; the feeling of comfort and the productivity of the building's users. Some of these criteria can create contradictory demands, such as the need for internal daylight illumination, which can reduce the need for artificial illumination but simultaneously increase the heat gain (Nielsen, Svendsen, and Jensen 2011).

To reduce artificial energy requirements for achieving indoor thermal comfort, intelligent building construction with approach of passive solar architecture is needed. (Ralegaonkar and Gupta, 2010).

Shading devices are the instruments used to reduce the incident radiation to supply thermally comfortable surroundings whereas decreasing the cooling load considerably. That is, shading devices reject the direct radiation and permit the diffuse element solely to be admitted (Duffie, 2013).

Cyprus, one of the largest islands in the Mediterranean has no petroleum reserves and is completely dependent on imported energy from petroleum products (AbuGrain & Alibaba, 2017). Sustainability issues and climate change as an effect of the use of fossil fuels are at the forefront of world issues. A practical 100% solution to these problems have not been developed, however it is clear that renewable energy solutions should spearhead the movement for its reconciliation. Solar strategy design in construction aims to control the flow of natural energy within the built environment thereby reducing mineral generated energy consumption and the attendant pollution emissions while ensuring a better quality of built environment.

An optimum shading device demonstrates a system providing maximum shading for a special period throughout the year (summer), while allowing maximum solar radiation in winter (Bader 2013). The total solar load consists of three components: direct, diffuse and reflected radiation. To prevent passive solar heating when it is not wanted, one must always shade a window from the direct solar component and often also from the diffuse sky and reflected components (Shahwarzi, 2014).

In the classic text by Victor Olgay (1963), which was revised in 2015, he argues that constructing buildings which respond to their regions through designing with climate in mind is a necessary and central part of modern architecture. Adaptive design and use, of building enclosures and elements seeks to solve constructive problems in a manner which is bio-climatically suitable to a region. This is achieved by exploiting the prevailing climate and user comfort variables, thereby facilitating the change from an artificially produced to a negotiated indoor climate. Assessment of existing physio climatic conditions on a macro and micro scale takes into consideration parameters such as Tilt of the Earth's Axis, Altitude, Azimuth Angles, hourly and daily lines and Sun Path.

Passive shading devices (PSDs) are shading elements adapted bio-climatically to suit the prevailing climate conditions within a region, without employing parts and systems which consume energy generated from the consumption of fossil fuels. They may be fixed in position or adjustable to weather changes on a daily or seasonal period. In achieving passive design, the orientation of the shading element is just as important as that of the building itself. Shading devices are classified as internal or external, depending on placement. The importance of Interior devices such as curtains, roller shades, Light shelves, Venetian blinds, and shutters may often be regarded less in comparison to external shading elements, but they are often less expensive, and adjustable which enables them to easily respond to changing requirements. Besides shading, these devices provide numerous other benefits, such as privacy, control, insulation, and interior aesthetics. At night, they also prevent the "black hole" effect created by exposed windows (Galloway, 2004).

Total energy consumption is decreased when energy consumption is reduced by the application of the horizontal shading device, and lighting energy consumption reduced by application of lighting control. External shading devices are designed to integrate into the building system and resist external conditions. Thus, they provide energy savings by reducing heat gain due to direct sunlight and by promoting glare free lighting of internal spaces. Hence, electrical and mechanical load are reduced, with concomitant decrease in costs (Kim, et al 2017).

Passive shading devices adapted to the high Mediterranean solar load include

1. Vertical and horizontal shading devices which may be fixed deep overhangs, louvers, fins, blinds, egg-crate and eaves. Movable variants of these elements include shutters, awnings, rotating fins and overhangs, rotating egg-crate and exterior roller shades.
2. Covered semi open spaces including balconies, porches and roofed terraces.
3. High performance materials including glazing with low shading coefficients, tints and reflective screens.
4. Double skin facades.
5. Massing techniques, which considers the shade afforded by a part of building massed over other parts, as well as cantilevers?
6. Vegetative shading elements including deciduous trees, green walls, screen plants, hedgerows and lawns.
7. Shading screens which include canopies, pergolas, Arbors and trellises.

3. Case Study

Cyprus is located at 35° N latitude of the equator and 34° E longitude and is the third largest island in the Mediterranean Sea after Sardinia and Sicily. The city of Gazimağusa (Famagusta) is a coastal town at the Eastern part of Cyprus with 7m elevation above sea level (Ozay, 2005). It is a fast-growing city bolstered economically by tourism, and immigrants occupied by the Eastern Mediterranean University (EMU). Famagusta receives an average of 5KWh/m^2 of solar radiation 9 hrs. daily, with July and August peaking at an of average temperature of 36 °C and 8.1 kWh/m^2 radiations; in contrast, the coldest months are December and January which receives an average of 2.3kWh/m^2 (Shahwarzi, 2014).

In assessing the adaptive use of shading devices to the region, two significant public buildings in Famagusta have been chosen for comparison to draw the case – The Eastern Mediterranean University Rectorate building and Lemar shopping mall. The case studies were chosen because of their size, relatively contemporary design, and build, having both been constructed within the decade. Additionally, both buildings are remarkably positioned as points of references to their locations, and are popular with regards to their functions. They are both public buildings which are designed to accommodate large numbers of transient people, albeit with two completely different uses.

PSDs employed in the cases are Building massing and cantilevers, Roof eaves and overhangs, Porches/balconies, Fixed Aluminum horizontal running fins (louvers) and Fixed vertical running fins. Internally, both buildings utilized blinds as a support to external shading systems, and also as primary devices.

3.1. EMU Rectorate Office Building

Fig 1. Aerial View of Emu Rectorate Office Building
(Image Courtesy of Google Maps, 2017)

The EMU Rectorate office building was commissioned in 2013 and consists of offices and meeting rooms to house the primary administrative functions of the university.

Its geometrically shaped floor plan contains a central courtyard and rises to two suspended floors. Its facade is finished with a combination of Aluminum Composite Material (ACM) panels, painted masonry and granite tiling. Large walls of glass siding on the interior courtyards and external facade provide full views and admit natural light. The building sits on a large open terrace finished with glossy granite tiles and covers approximately 2,588m^2 of floor space.

Fig 2. Showing Sunrise on Eastern Elevation and Suspended Floor on Northern Elevation (Chinweokwu and Alibaba's Archive, 2017)

The EMU Rectorate office building features a relatively uninterrupted linear facade with few pronounced mass projections and recesses on its exposed Southern, Eastern and Western elevations. Where present, projections and recesses are of insufficient depth to count as shading devices. However, on its Northern face the building features a suspended top floor, overhanging a porch thus suitably shading glazed walls and windows beneath it. Cantilevers were employed on the Southern and Eastern facades, admitting winter sunlight to windows beneath it and providing partial shade in the summer. Eastern windows overhung by cantilevers received no further external shading treatment, but the Southern windows were aided by closely spaced vertical fins.

Fig 3. Showing Suspended Floors and Cantilevered Masses - Northern Facade
(Chinweokwu and Alibaba's Archive, 2017)

Fig 4. Concrete Pergola over Terrace - Western Facade
(Chinweokwu and Alibaba's Archive, 2017)

The courtyard spaces of the facility feature glass walls promoting a light, airy and open feel to the environment. However, angle of incident sunlight, relatively low building heights and wide spans of courtyard space renders building mass less effective as a shading technique in the spaces open to, and adjoining the courtyard. These spaces received very little external shade treatments, admitting sunlight freely and directly with attendant thermal effects. Consequently, in 2017 corrective work was partially carried by installing aluminum fins on exposed glass facades in the courtyard.

The EMU Rectorate office building employs minimal use of roof eaves, designed instead with parapet walls extending as a continuation of exterior walls, and terminating without eave overhangs. An outdoor terrace on the first floor is covered by a concrete pergola of uncrossed, West facing beams. Closely spaced vertical fins feature on the ground floor of the building, along its Southern facade to limit angle of incidence sun rays.

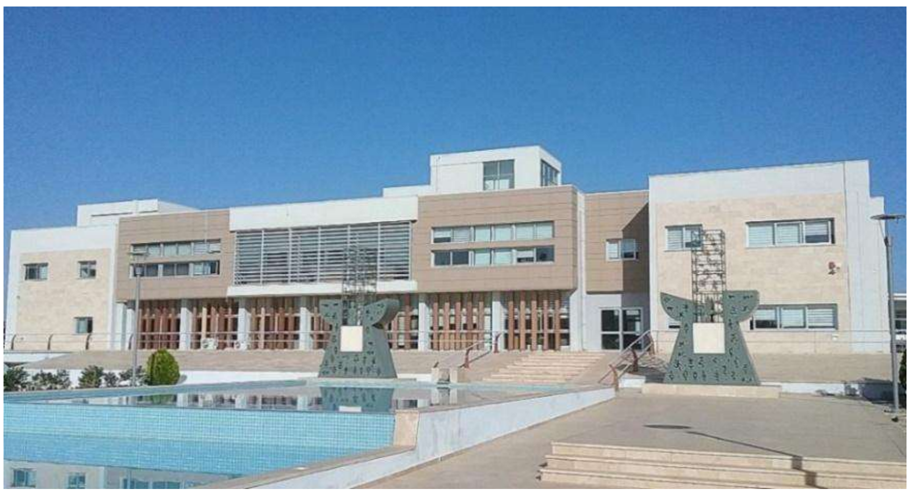

Fig 5. Showing Facade of Emu Rectorate Office - South Facade
(Chinweokwu and Alibaba's Archive, 2017)

The EMU Rectorate office building employed horizontal, Aluminum louvers as a primary shading device for larger windows.

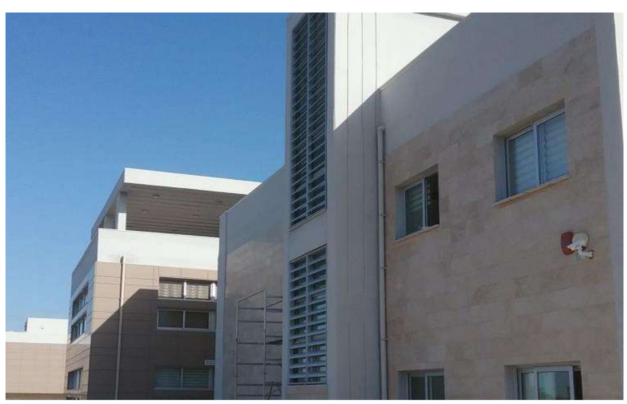

Fig 6. Selective Shading of Windows at Emu Admin Building - West Facade
(Chinweokwu and Alibaba's Archive, 2017)

2. Lemar Shopping Complex

Fig 7. Aerial View of Lemar Shopping Mall (Image Courtesy of Google Map, 2017)

Lemar shopping mall is a public commercial building located along Salamis road, in the Gulseren region of Famagusta, and caters to the entertainment and shopping needs of the residents of Famagusta. The main entrance to the building opens into a central atrium, with a food court running along the left of its ground hall, and a store style shopping center occupying the majority parts of the ground and first floor. The second floor houses a game arcade and cinemas.

The building is formed as an irregular geometric shape, intersected by a curvilinear sliver to one side, and massed to two suspended floors. Its main entrance faces the Salamis Street at a North-Eastern orientation. It covers an approximate floor area of 4,273m^2.

The approach of Lemar shopping mall (North-Eastern elevation) consists of two main building masses - a cuboid bulk projecting from the main body, and a curvilinear glazed mass, shaped in a half moon to intersect the main structure and rising like a ship's bow. The orientation of the North facing entrance precludes direct sunlight, and is shaded from the East by the protruding curvilinear glass mass. In this instance shading was achieved by orientation and massing, thus requiring no further treatment.

Fig 8. Main Approach to Lemar Shopping Mall (North-Eastern Elevation) Showing Shaded Entrance to Mall. (Chinweokwu and Alibaba's Archive, 2017)

The same configuration is repeated on the South-Western elevation, but with less success, as sustained sunlight occurs from the West and South. Insufficiently recessed curtain walls and windows on the facade admit direct and sustained sunlight from the West, East and South (see Fig 11). The South-Eastern and North-Western facades are largely linear in form, and have fewer projections and recesses.

Lemar shopping complex building is overhung with roof eaves on the South-Western and North-Eastern elevations but devoid of any on other facades, which feature less windows. These eaves prevent the direct admission of overhead sunlight, especially in the hot summer months when it is undesirable.

Fig 9. Continuous Horizontal Aluminium Fins Employed on Upper Facade of Lemar Building (Chinweokwu and Alibaba's Archive, 2017)

Fig 10. Continuous Horizontal Aluminium Fins Employed on Upper Facade of Lemar Building (Chinweokwu and Alibaba's Archive, 2017)

Horizontally running, aluminum louvered fins were employed as the primary, fixed external shading device for windows and curtain walls on both buildings. The Lemar shopping mall building features louvers for shading on the glazed regions of the upper floors of the building. These inclined horizontal Aluminum fins effectively blind the South-Eastern, South, and

South-Western sunlight from the building. However, several windows beside the primary curtain walls were not afforded any external shading.

Fig 11. South Western Elevation Showing Partial Recessing and Use of Shading Louvers (Chinweokwu and Alibaba's Archive, 2017)

The ground floors do not feature the louvers employed on upper floors, and have clear shopping style display. However, they contend with glare and overheating in the summer and comfort months, from reflected sunlight. The Lemar shopping mall employs selective and minimal use of blinds, favoring exposed views to the internal areas in a typical display style. On lower floors where no external shading devices were used, internal vertical blinds were employed as the primary means of shading from direct and reflected sunlight, as well as accompanying glare.

Table 1. Summary of PSD Usage At Emu Rectorate Office and Lemar Shopping Complex

	*PSD type	EMU admin block	Lemar shopping mall
1.	Building massing and cantilevers	• Few pronounced recesses and projections • Cantilever on South and Eastern facade, provides shade in summer, admits winter sunlight.	Shading by massing on North Eastern face Shading by massing with limited success on South -Western.
2.	Roof eaves and overhangs	• Absent, employing straight parapet walls.	• Present, selectively employed

3.	1. Porches and balconies	• Porch on main entrance face. • Pergola to shade terrace on Western wing.	□ Absent
4.	Fixed horizontal running fins (louvers)	• Present, selectively employed	□ Present, selectively employed
5.	Fixed vertical running fins	• Present, on ground floor of Southern facade.	□ Absent.
6.	Roller Blinds	• Present, venetian blinds.	• Present, vertical blinds, selectively used.

*PSD – Passive Shading Devices

4. Findings and Discussion

In a questionnaire survey to determine the thermal comfort levels of the workers at the EMU rectorate office, 30 permanent, daytime staff were selected randomly to fill out questionnaires on the perception of the solar heating effects achieved inside the building. Constant use of internal blinds as shown in fig 12 and 12.1 below suggests a high incidence of discomfiting sunlight. While 37% (n = 11) of the populace indicated content with the level of shading achieved by use of blinds alone, 77% (n = 23) of these had offices with a Northern window orientation thus receiving minimal direct sunlight. 93% (n = 28) of the population indicated the need for more shading for the building overall, as well as indicating that the building admits too much sunlight. 100% (n = 30) of users with offices on the South and Western facades use their blinds all day long in summer, and 93% (n = 28) believe direct sunlight is a major cause of heating in the office spaces at that time. In winter 53% (n = 16) of user offices oriented to the East, West and South received enough sunlight to help warm their office naturally.

EMU Rectorate Office Building

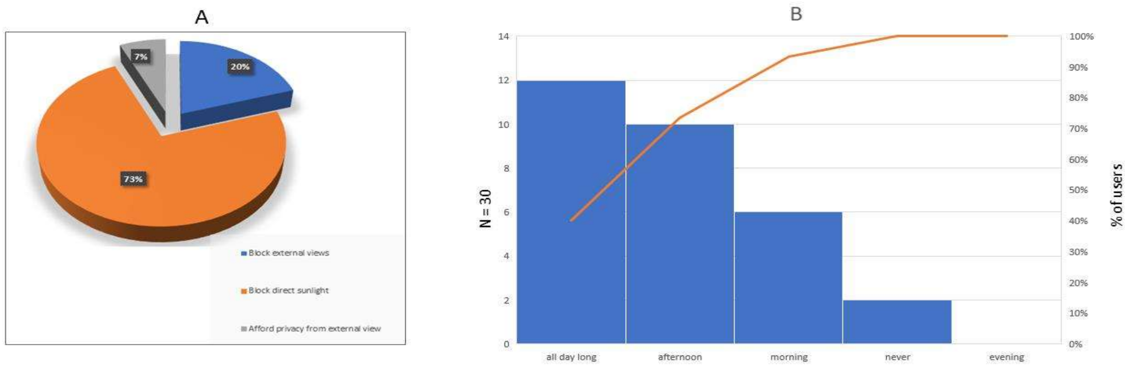

Fig 12. User indication of primary use for blinds (A) and user indication of times of undesirably admitted light (B).

At the Lemar shopping mall, 25 permanent daytime staff and 3 regular patrons filled out questionnaires on the perception of the solar heating effects achieved inside the building. The populace indicated satisfaction with the level of shading achieved generally, 86% (n = 24) also observed that windows without shade on the South-Western facade contributed to internal heating in the summer, as shown in fig 13. This region was also indicated as hottest, and 90% (n = 25) showed the upper floors of the region as hardest to cool. The results and findings show that while the Lemar shopping mall features greater spans of glazing on its external facade, its employ of a combination of massing techniques and an Aluminum louver system is effective enough to provide the right balance of lighting and thermal comfort generally. Comparatively, the users at the EMU rectorate office building indicated the use of blinds for most of the day, suggesting a necessity to block off excess heat and light rays from the sun.

Lemar Shopping Mall

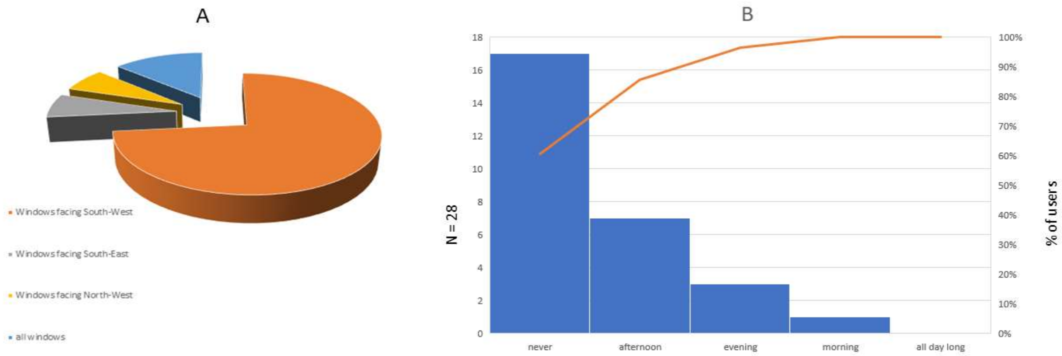

Fig 13. User indication of direction of admitted sunlight (A) and user indication of times of undesirably admitted light (B).

Deficiencies in the Lemar building include compromises on the ground floor in favor of display, as views into and from spaces shaded with the louver system are severely limited. The South-Western facade also feature several unshaded windows and glazing, admitting direct sunlight to a region which users indicated as hottest, and hardest to cool.

The EMU Rectorate building features a greater variety of shading devices, however insufficient quantitative use exposes several windows on all facades to direct sunlight, necessitating a constant use of internal blinds. On the Northern facade, a suspended floor overhangs an entrance porch, which also shades the underlying glazed walls and windows, but the shading advantage is however, better suited to a Western or Southern facade. Likewise, a large Western oriented roof terrace is shaded by a pergola of single dimension beams, also oriented Westward, therefore offering less resistance to the path of incident rays. A lattice frame pergola provides better and enduring shading from different directions. The South facade features close spaced vertical fins, limiting angled sunlight. However, vertical fins were not used on the Eastern and Western facades which receive angled sun rays and where vertical shading elements would be more effective, hinting at the likelihood of aesthetic consideration over the functional.

The use of louvered systems as a primary shading device in these public buildings is appropriate and effective when applied to sufficient coverage. However, other bioclimatic shading methods were employed sparingly or ignored completely. Vertical/horizontal shutters or fins will appropriately shade Western and Eastern windows, as well as deep overhangs which could be extended into Brise-Soleil and egg-crate systems. Canopies and porches provide a cool restful space as well as providing deep shade. Other options include double skin facades, optimized glazing and screens which should be adopted on future projects.

The immediate surroundings of both buildings feature continuous hard surfaces (Polished granite slab external flooring at EMU Rectorate building and a combination of concrete interlocking tiles and bituminous pavement at Lemar mall) which promotes glare from reflected sunrays. Vegetative ground like grasses, as well as shrubs should be employed in immediate surroundings to break incident sun rays. This is applicable to roof terraces as well, in line with sustainable construction goals and especially in situations where differing floor levels provide an opportunity for reflecting rays to impact windows at a lower, unprotected angle. Trees and shrubs around buildings is a desirable way of achieving shade and breaking direct sunlight.

5. Conclusion

The Mediterranean climate of Famagusta requires bioclimatic use of shading devices to preclude direct sunlight in the hot months of the year, through glazed surfaces and building openings. Inversely, these devices should accommodate incident sunlight in the winter to warm up spaces naturally. In both cases the successful use of such devices should significantly reduce the use of fossil fuel energized mechanical systems. Observation of shading devices on two case study public buildings indicates passive design awareness, as employed in their shading systems, primarily employing louvered fins and massing techniques externally, as well as adjustable blinds internally. However, user perception of thermal comfort levels carried out in a survey of the buildings suggests limited success. This evaluation is backed by observation of inadequate quantitative use of employed shading devices.

In the EMU Rectorate building, externally fixed aluminum louvers and internally set Venetian blinds were employed as the primary means of passively shading the building. Louvers were employed selectively, covering less than 20% of windows and glazed surfaces, and indicating superior consideration for its aesthetic value. Likewise, the Lemar shopping mall entrance region is shaded by applying successful massing techniques in relation to building orientation. The facility features Aluminum louvers as a primary shading device, wrapping around major glazed regions. However, inadequate treatment of glazed regions and windows, on the South-Western facades admits sustained late sunlight, with consequent user perception indicating spaces in the region to be the most uncomfortably heated.

It can be deduced that the PSDs applied to these buildings are more generic than adaptive, as features which are characteristic of passive cooling techniques in the Mediterranean have not been employed sufficiently. Further research is required to build on a module for adaptable passive systems, and the findings from this study will be used as reference data for the design of optimal shading devices suitable to the North Cyprus regions.

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