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OPTIMIZATION OF PASSIVE SOLAR DESIGN STRATAGIES IN HOT CLIMATE (CYPRUS)

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Abstract: **This paper basically illustrates a series studies and analysis to optimize the use of passive solar design in aim of thermal comfort in living spaces in Cyprus, during hot season. First, we state, different ways to optimize passive solar design in living spaces having different alternatives and choosing the best strategy by series of analysis and simulations.first, for the studies we monitored the indoor temperature of the spaces, from sunrise to sunset this would be the default temperature and then determine through simulations, how these passive solar design strategies affects the indoor temperature positively. Therefore, in this paper we would go through these strategies of optimizing passive solar design in living spaces and then finally suggest the best strategy to consider to improve the thermal performance of the space.**

Keywords: **Thermal mass, South façade, Openings. Passive solar design.**

1. INTRODUCTION

The idea of passive solar design is basically using the sun energy in the right approach to cool the living spaces as the case may be of it is in a hot climate. According to this, we have to understand how to apply passive solar design in a way that it can be effective in cooling our living spaces adequately. Passive solar design takes advantage of the site, climate, and materials to minimize energy use.in the building. A well-designed solar home must have ability to provide comfort during cooling seasons and also in hot seasons Passive design in buildings uses building architecture to minimize the energy utilization of the building and enhances the warm solace of the. The main considerations of the passive design approaches are to reduce the energy use of the building and to increase the thermal comfort of the occupants. In general, the main aim of a passive solar designs in buildings depends on natural sources of energy and reduces the need for mechanical systems for cooling, heating, and lighting in the building. Contemporary design construction in Cyprus is not so good because most times they do not take passive heating strategies into consideration. They quality of an indoor space has to do with how comfortable it is in terms of thermal comfort. Thermal comfort is an important topic to consider when designing a sustainable design, in Cyprus the weather conditions are extreme in the sense that it gets too cold in the winter period and gets too hot in the summer period. My study basically will deal mostly on thermal comfort in summer period. According to my research, we would discuss basically the different strategies in passive solar design and state which of these strategies best cools a space adequately. First knowing how passive solar systems work how they can be applied to living spaces, and finally recommending the best procedure to follow while considering a passive solar design.

2. LITEREATURE REVIEW

Designing in Cyprus basically passive solar design is not usually applied in student apartment because most times, mechanical solutions are used in ventilating the space hereby causing pollution to the environment and to occupants. According to article by Piers MacNaughton, James Pegues, Usha Satish, Suresh Santanam, John Spengler, Joseph Allen

Buildings account for 41% of US energy consumption, with nearly half of that energy usage coming from the commercial sector [1]. In office buildings, over half of the end-use energy expenditures are attributable to heating, ventilating, and cooling [2]. The environmental impact of these energy expenditures has been well documented; greenhouse gases emitted during power production are associated with climate change impacts including rising sea level, extreme temperatures, and more frequent weather events [3,4]. Emissions of sulfur dioxide (SO2) contribute to acid rain, which can damage sensitive ecosystems [5]. More important, however, are the downstream human health effects related to these environmental impacts. Elevated temperatures and droughts will increase the likelihood of heat-related illness and mortality [6]. Extreme weather effects also pose health and economic risks, especially in developing regions [7]. Emissions from power plants also have several direct health effects: (1) exposure to particulate matter, in particular SO2, increases the risk of respiratory and cardiovascular disease and (2) nitrogen oxides (NOx) cause airway inflammation and respiratory symptoms, especially in asthmatics [8,9].

At the building level, buildings managers are incentivized to reduce costs, which often is achieved by reducing ventilation rates. Similar incentives are not set for optimizing the health performance of buildings as occupant health is more difficult to characterize. Further, building managers tend to overestimate the energy costs related to ventilation. When asked the cost per occupant to double the ventilation rate from 20 cfm/person to 40 cfm/person and improve filtration from a minimum efficiency reporting value (MERV) 6 to a MERV 11 filter, building managers reported a perceived cost per occupant of $100 while the modeled estimates were consistently below $32 per occupant for all climate zones [10].

Consultants, tenants and owners also overestimated the costs of improved ventilation per occupant at $60, $115, and $80, respectively. Owners and building managers believe that tenants do not consider indoor air quality (IAQ) when leasing a space: 58% of respondents reported that 20% or less of their tenants take IAQ into consideration [10]. As a result, the cost of energy is often prioritized over IAQ and minimum required ventilation rates are met.

Mechanical ventilation can have lots of negative impacts but due to the fact that it is much more used but on the long run it could be a disadvantage. To attain a sustainable design a building, design has to minimize the amount of energy consumed. In view of www.gsa.gov/sustainabledesign.

Sustainable design seeks to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability are to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments. Sustainable design principles include the ability to:

- optimize site potential;
- minimize non-renewable energy consumption;
- use environmentally preferable products;
- protect and conserve water;
- enhance indoor environmental quality; and
- optimize operational and maintenance practices.

Utilizing a sustainable design philosophy encourages decisions at each phase of the design process that will reduce negative impacts on the environment and the health of the occupants, without compromising the bottom line. It is an integrated, holistic approach that encourages compromise and tradeoffs. Such an integrated approach positively impacts all phases of a building's life-cycle, including design, construction, operation and decommissioning.

To attain an effective passive solar design, we have properly orientated our buildings in the best position to get enough sunlight into the living spaces.

According to http://www.level.org.nz/fileadmin/downloads/Other_Resources/Passive_Solar_Design.pdf For maximum solar gain, a building will be located, oriented and designed to maximize window area facing north (or within 20 degrees of north) – for example, a shallow east-west floor plan. However, this will depend on the site's shape, orientation and topography. For example, an east-west floor plan will not be possible on a narrow north-south site.

Orientation for solar gain will also depend on other factors such as proximity to neighboring buildings and trees that shade the site. Or solar gain, as well as considering location, orientation and window size and placement, it is also important to consider the thermal performance and solar heat gain efficiency of the glazing unit itself (see glazing and glazing units for more information). While solar gain for passive heating is important, other considerations include noise, daylighting, protection from prevailing winds, access to breezes for ventilation, shade to prevent summer overheating and glare, views, privacy, access, indoor/outdoor flow, owners' preferences, and covenants and planning restrictions. Where passive cooling is more of a priority than passive heating, the building should be oriented to take advantage of prevailing breezes. Orientation, location and layout should be considered from the beginning of the design process – ideally, from the time the site is being selected. Once a building has been completed, it is impractical and expensive to reorient later. Good orientation, together with thermal mass and the right glazing and insulation, can cut the heating requirements in a house by half or more, reducing energy costs and greenhouse gas emissions. Effective solar orientation requires a good understanding of sun paths at the site at different times of the year.

Another thing to consider is openings on your building, they have to be design in a way to get enough sunlight needed to heat the space. And also, thermal mass of the building. (http://energy.gov/eere/femp/federal-energy-management-program)

Effective thermal mass materials, like concrete, or stone floor slabs, have high specific heat capacities, as well as high density. It is ideally placed within the building where it is exposed to winter sunlight but insulated from heat loss. The material is warmed passively by the sun and releases the thermal energy into the interior during the night. The most important characteristic of passive solar design is that it is holistic, and relies on the integration of a building's architecture, materials selection, and mechanical systems to reduce heating and cooling loads. It is also important to consider local climate conditions, such as temperature, solar radiation, and wind, when creating climate-responsive, energy conserving structures that can be powered with renewable energy sources.

In climates that are appropriate for passive solar heating, large south-facing windows are used, as they have the most sun exposure in all seasons. Although passive solar heating systems do not require mechanical equipment for operation, fans or blowers may be used to assist the natural flow of thermal energy. The passive systems assisted by mechanical devices are referred to as hybrid heating systems.

Passive solar systems utilize basic concepts incorporated into the architectural design of the building. This typically includes buildings with rectangular floor plans, elongated on an east-west axis, a glazed south-facing wall, a thermal storage media exposed to the solar radiation which penetrates the south-facing glazing, overhangs, or other shading devices, which sufficiently shade the south-facing glazing from the summer sun, and windows on the east and west walls, and preferably none on the north walls.

To achieve a high percentage of passive solar heating, it is necessary to incorporate adequate thermal mass in buildings. Specific guidelines for this include the following:

- Confirm that the area of thermal mass is six times the area of the accompanying glazing (when possible). For climates with foggy or rainy winters, somewhat less thermal mass is needed.

- Place the mass effectively by ensuring that it is directly heated by the sun or is spread in thin layers throughout rooms in which there is a large quantity of solar collection.

- Disregard the color of the mass surface. However, natural colors (e.g. colors in the 0.5 to 0.7 absorption range) are quite effective.

- Incorporate thermal storage in floors or walls that consist of concrete, masonry, or tile. To reflect light and enhance the space, walls should generally remain light colored.

3. METHODOLOGY

In my study, a series of field studies were conducted. Also, simulation software, to conduct an energy study on building which represents the warmest period during the summer. The thermal simulation analysis was carried out by applying passive design strategies to the simulation software, such as orientation, shading devices, thermal mass, insulation, and natural ventilation. This starts by investigating various strategies to predict the optimum conditions of a building in Cyprus in the hottest period of the year. The simulation results determined how to improve the thermal performance of the building and how to design spaces that are more comfortable for occupants by using passive design strategies, and as a result to reduce the energy consumption of the building, hereby archiving a sustainable design.

My case study building is the Alfam c block dormitory, according to my study, I took a field analysis by going to the rooms facing the true south façade and also the rooms in the true north I checked the temperature of the spaces at its state first to determine the initial temperature before adding my passive design strategies and determine how to perfectly optimize the spaces. To achieve thermal comfort. After these, I used my simulation software to determine how to achieve thermal comfort by now applying my passive solar design strategies to my model.

The main aim of the field measurements is to be able to predict the comfort temperature levels in the dorm spaces and their thermal satisfaction while occupants are using the spaces in different times of the day. The results were used to evaluate and improve the building's thermal performance with the use of thermal simulation software. According to the field analysis conducted in two rooms which represents all the rooms in the dormitory, first I checked the temperature of the room spaces in different times of the day. First and sunrise 5am-9am, midday 11am-2pm, sunset 5pm-7pm. Summer periods in Cyprus arrives in June and august.

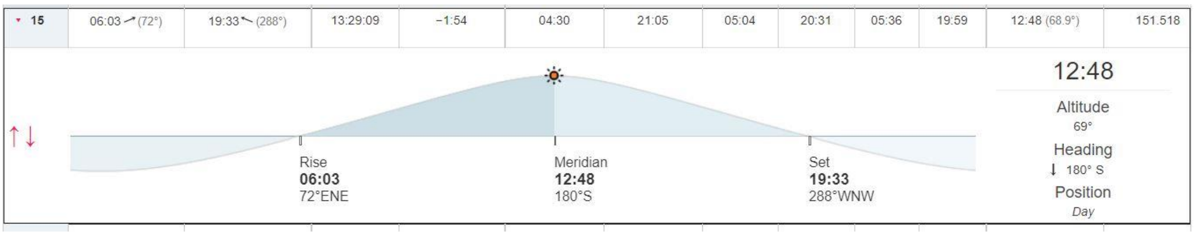
Fig 3.1 https://doi.org/10.3389/fbuil.2016.00003

2018	Sunrise/Sunset		Daylength		Astronomical Twilight		Nautical Twilight		Civil Twilight		Solar Noon	
Aug	Sunrise	Sunset	Length	Difference	Start	End	Start	End	Start	End	Time	Mil. km
1	05:53 ↗ (67°)	19:47 ↖ (293°)	13:54:12	−1:37	04:15	21:24	04:51	20:48	05:25	20:15	12:50 (72.9°)	151.835
2	05:53 ↗ (67°)	19:46 ↖ (292°)	13:52:33	−1:38	04:16	21:23	04:52	20:47	05:26	20:14	12:50 (72.6°)	151.817
3	05:54 ↗ (68°)	19:45 ↖ (292°)	13:50:53	−1:40	04:17	21:22	04:53	20:46	05:26	20:13	12:50 (72.4°)	151.798
4	05:55 ↗ (68°)	19:44 ↖ (292°)	13:49:11	−1:41	04:18	21:21	04:54	20:45	05:27	20:12	12:50 (72.1°)	151.779
5	05:56 ↗ (68°)	19:43 ↖ (291°)	13:47:28	−1:43	04:19	21:19	04:55	20:44	05:28	20:11	12:50 (71.8°)	151.759
6	05:56 ↗ (69°)	19:42 ↖ (291°)	13:45:43	−1:44	04:20	21:18	04:56	20:43	05:29	20:10	12:50 (71.5°)	151.738
7	05:57 ↗ (69°)	19:41 ↖ (291°)	13:43:57	−1:45	04:22	21:17	04:57	20:42	05:30	20:09	12:49 (71.3°)	151.717
8	05:58 ↗ (69°)	19:40 ↖ (290°)	13:42:10	−1:47	04:23	21:15	04:58	20:40	05:31	20:08	12:49 (71.0°)	151.695
9	05:59 ↗ (70°)	19:39 ↖ (290°)	13:40:22	−1:48	04:24	21:14	04:59	20:39	05:31	20:06	12:49 (70.7°)	151.672
10	06:00 ↗ (70°)	19:38 ↖ (290°)	13:38:32	−1:49	04:25	21:12	04:59	20:38	05:32	20:05	12:49 (70.4°)	151.648
11	06:00 ↗ (71°)	19:37 ↖ (289°)	13:36:42	−1:50	04:26	21:11	05:00	20:37	05:33	20:04	12:49 (70.1°)	151.624
12	06:01 ↗ (71°)	19:36 ↖ (289°)	13:34:50	−1:51	04:27	21:10	05:01	20:35	05:34	20:03	12:49 (69.8°)	151.598
13	06:02 ↗ (71°)	19:35 ↖ (288°)	13:32:57	−1:52	04:28	21:08	05:02	20:34	05:35	20:02	12:49 (69.5°)	151.572
14	06:03 ↗ (72°)	19:34 ↖ (288°)	13:31:04	−1:53	04:29	21:07	05:03	20:33	05:36	20:01	12:48 (69.2°)	151.545
15	06:03 ↗ (72°)	19:33 ↖ (288°)	13:29:09	−1:54	04:30	21:05	05:04	20:31	05:36	19:59	12:48 (68.9°)	151.518
16	06:04 ↗ (72°)	19:31 ↖ (287°)	13:27:13	−1:55	04:31	21:04	05:05	20:30	05:37	19:58	12:48 (68.6°)	151.489
17	06:05 ↗ (73°)	19:30 ↖ (287°)	13:25:17	−1:56	04:32	21:02	05:06	20:29	05:38	19:57	12:48 (68.3°)	151.460
18	06:06 ↗ (73°)	19:29 ↖ (287°)	13:23:20	−1:57	04:34	21:01	05:07	20:27	05:39	19:56	12:48 (67.9°)	151.431
19	06:06 ↗ (74°)	19:28 ↖ (286°)	13:21:21	−1:58	04:35	20:59	05:08	20:26	05:40	19:54	12:47 (67.6°)	151.401
20	06:07 ↗ (74°)	19:27 ↖ (286°)	13:19:22	−1:58	04:36	20:58	05:09	20:25	05:41	19:53	12:47 (67.3°)	151.370
21	06:08 ↗ (74°)	19:25 ↖ (285°)	13:17:23	−1:59	04:37	20:56	05:10	20:23	05:41	19:52	12:47 (67.0°)	151.339
22	06:09 ↗ (75°)	19:24 ↖ (285°)	13:15:22	−2:00	04:38	20:55	05:11	20:22	05:42	19:50	12:47 (66.6°)	151.308
23	06:09 ↗ (75°)	19:23 ↖ (284°)	13:13:21	−2:01	04:39	20:53	05:12	20:20	05:43	19:49	12:46 (66.3°)	151.276
24	06:10 ↗ (76°)	19:21 ↖ (284°)	13:11:19	−2:01	04:40	20:51	05:12	20:19	05:44	19:48	12:46 (65.9°)	151.244
25	06:11 ↗ (76°)	19:20 ↖ (284°)	13:09:17	−2:02	04:41	20:50	05:13	20:18	05:45	19:46	12:46 (65.6°)	151.212
26	06:12 ↗ (77°)	19:19 ↖ (283°)	13:07:14	−2:03	04:42	20:48	05:14	20:16	05:45	19:45	12:46 (65.3°)	151.179
27	06:12 ↗ (77°)	19:18 ↖ (283°)	13:05:10	−2:03	04:43	20:47	05:15	20:15	05:46	19:44	12:45 (64.9°)	151.146
28	06:13 ↗ (77°)	19:16 ↖ (282°)	13:03:06	−2:04	04:44	20:45	05:16	20:13	05:47	19:42	12:45 (64.6°)	151.113
29	06:14 ↗ (78°)	19:15 ↖ (282°)	13:01:01	−2:04	04:45	20:44	05:17	20:12	05:48	19:41	12:45 (64.2°)	151.079

Fig 3.2 https://doi.org/10.3389/fbuil.2016.00003

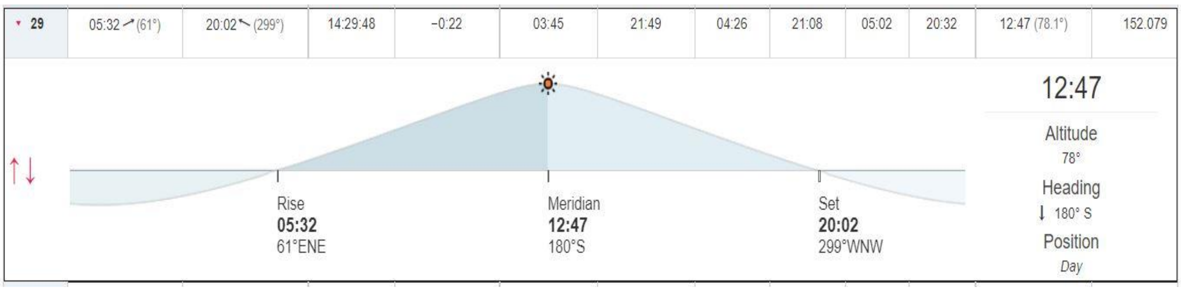
2018	Sunrise/Sunset		Daylength		Astronomical Twilight		Nautical Twilight		Civil Twilight		Solar Noon	
Jun	Sunrise	Sunset	Length	Difference	Start	End	Start	End	Start	End	Time	Mil. km
1	05:31 ↗ (62°)	19:53 ↖ (298°)	14:21:43	+0:57	03:46	21:37	04:26	20:58	05:02	20:22	12:41 (77.0°)	151.691
2	05:30 ↗ (62°)	19:53 ↖ (298°)	14:22:38	+0:55	03:46	21:38	04:25	20:59	05:01	20:22	12:42 (77.1°)	151.714
3	05:30 ↗ (62°)	19:54 ↖ (298°)	14:23:31	+0:52	03:45	21:39	04:25	20:59	05:01	20:23	12:42 (77.2°)	151.737
4	05:30 ↗ (62°)	19:54 ↖ (299°)	14:24:21	+0:49	03:45	21:40	04:24	21:00	05:01	20:24	12:42 (77.3°)	151.759
5	05:30 ↗ (61°)	19:55 ↖ (299°)	14:25:08	+0:47	03:44	21:41	04:24	21:01	05:00	20:24	12:42 (77.4°)	151.781
6	05:30 ↗ (61°)	19:55 ↖ (299°)	14:25:53	+0:44	03:44	21:41	04:24	21:01	05:00	20:25	12:42 (77.6°)	151.802
7	05:29 ↗ (61°)	19:56 ↖ (299°)	14:26:35	+0:41	03:43	21:42	04:23	21:02	05:00	20:25	12:43 (77.6°)	151.822
8	05:29 ↗ (61°)	19:56 ↖ (299°)	14:27:14	+0:39	03:43	21:43	04:23	21:03	05:00	20:26	12:43 (77.7°)	151.842
9	05:29 ↗ (61°)	19:57 ↖ (299°)	14:27:50	+0:36	03:43	21:43	04:23	21:03	04:59	20:27	12:43 (77.8°)	151.862
10	05:29 ↗ (61°)	19:57 ↖ (299°)	14:28:24	+0:33	03:43	21:44	04:23	21:04	04:59	20:27	12:43 (77.9°)	151.880
11	05:29 ↗ (61°)	19:58 ↖ (299°)	14:28:54	+0:30	03:42	21:45	04:23	21:04	04:59	20:28	12:43 (78.0°)	151.898
12	05:29 ↗ (61°)	19:58 ↖ (299°)	14:29:22	+0:27	03:42	21:45	04:23	21:05	04:59	20:28	12:44 (78.0°)	151.914
13	05:29 ↗ (61°)	19:59 ↖ (299°)	14:29:47	+0:25	03:42	21:46	04:22	21:05	04:59	20:28	12:44 (78.1°)	151.930
14	05:29 ↗ (60°)	19:59 ↖ (300°)	14:30:09	+0:22	03:42	21:46	04:22	21:06	04:59	20:29	12:44 (78.2°)	151.945
15	05:29 ↗ (60°)	19:59 ↖ (300°)	14:30:29	+0:19	03:42	21:47	04:22	21:06	04:59	20:29	12:44 (78.2°)	151.959
16	05:29 ↗ (60°)	20:00 ↖ (300°)	14:30:45	+0:16	03:42	21:47	04:22	21:06	04:59	20:30	12:44 (78.2°)	151.972
17	05:29 ↗ (60°)	20:00 ↖ (300°)	14:30:58	+0:13	03:42	21:47	04:23	21:07	04:59	20:30	12:45 (78.3°)	151.985
18	05:29 ↗ (60°)	20:00 ↖ (300°)	14:31:09	+0:10	03:42	21:48	04:23	21:07	04:59	20:30	12:45 (78.3°)	151.996
19	05:29 ↗ (60°)	20:01 ↖ (300°)	14:31:16	+0:07	03:42	21:48	04:23	21:07	05:00	20:31	12:45 (78.3°)	152.007
20	05:30 ↗ (60°)	20:01 ↖ (300°)	14:31:21	+0:04	03:42	21:48	04:23	21:08	05:00	20:31	12:45 (78.3°)	152.017
21	05:30 ↗ (60°)	20:01 ↖ (300°)	14:31:22	+0:01	03:42	21:49	04:23	21:08	05:00	20:31	12:45 (78.3°)	152.026
22	05:30 ↗ (60°)	20:01 ↖ (300°)	14:31:21	−0:01	03:43	21:49	04:23	21:08	05:00	20:31	12:46 (78.3°)	152.034
23	05:30 ↗ (60°)	20:02 ↖ (300°)	14:31:16	−0:04	03:43	21:49	04:24	21:08	05:00	20:31	12:46 (78.3°)	152.042
24	05:31 ↗ (60°)	20:02 ↖ (300°)	14:31:09	−0:07	03:43	21:49	04:24	21:08	05:01	20:31	12:46 (78.3°)	152.050
25	05:31 ↗ (60°)	20:02 ↖ (300°)	14:30:58	−0:10	03:43	21:49	04:24	21:08	05:01	20:32	12:46 (78.3°)	152.057
26	05:31 ↗ (60°)	20:02 ↖ (300°)	14:30:45	−0:13	03:44	21:49	04:25	21:08	05:01	20:32	12:47 (78.2°)	152.063
27	05:31 ↗ (60°)	20:02 ↖ (300°)	14:30:29	−0:16	03:44	21:49	04:25	21:08	05:02	20:32	12:47 (78.2°)	152.069
28	05:32 ↗ (60°)	20:02 ↖ (300°)	14:30:10	−0:19	03:45	21:49	04:25	21:08	05:02	20:32	12:47 (78.2°)	152.074
29	05:32 ↗ (61°)	20:02 ↖ (299°)	14:29:48	−0:22	03:45	21:49	04:26	21:08	05:02	20:32	12:47 (78.1°)	152.079

Fig 3.3 https://doi.org/10.3389/fbuil.2016.00003



Sun graph showing temperature on different times of the day.

Fig 3.4 https://doi.org/10.3389/fbuil.2016.00003



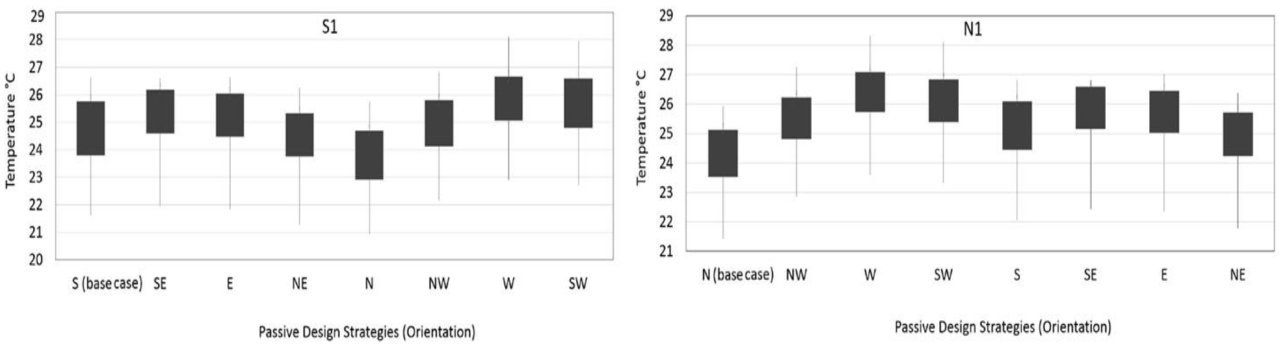
In order to assess and improve the indoor thermal performance of the dorm spaces based on the passive design strategies and occupants' thermal comfort, thermal simulation analysis was performed in two rooms one on the south and another on the north using Design Builder. The simulation analysis was carried out for the field studies, using rooms facing north

(N1) and south (S1) of the building The field studies' results were also added to the simulation model in Design Builder in order to check the current thermal performance of the alfam dormitory. Later, various passive design strategies were applied to the simulation model separately and the impact of these strategies, including orientation, solar shading devices, thermal mass, natural ventilation as well as external wall, and roof insulation on indoor air temperatures in summer season, was analyzed by revising the case study model in order to identify the optimal solution for each space. Following this, the optimum design solutions were defined for the case study building by combining all the optimal design solutions for each parameter. In order to improve the thermal performance of the school dormitory, passive design strategies, including orientation, shading devices, insulation materials thermal mass, and natural ventilation, the simulation analysis was performed on rooms South and North. These two rooms represented all the rooms in analyzing the impact of passive design strategies on indoor air temperatures in various locations.

Building orientation can affect the needs for mechanical energy systems in the buildings. An appropriate building orientation can decrease the use of mechanical heating and cooling systems, and as a result, reduce energy bills of the building. Building orientation has an impact on heat gains of the building, as a result of the variety of solar radiation at different angles.

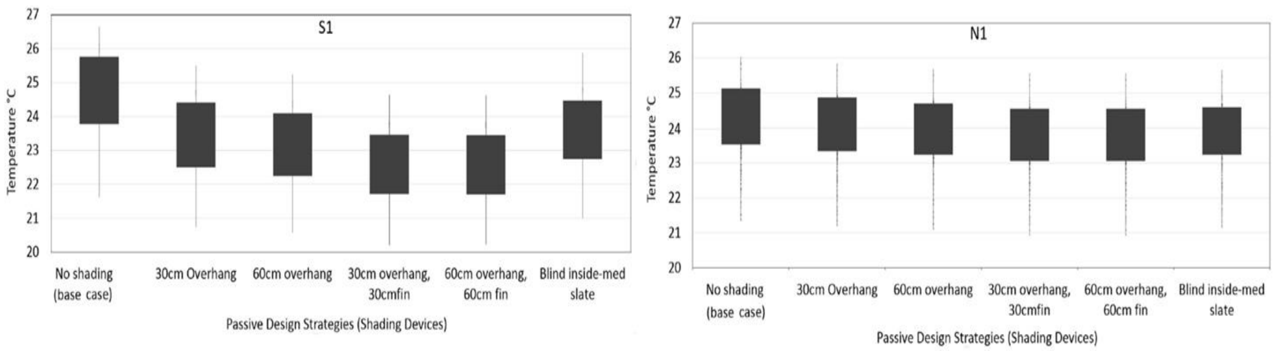
According to the analysis a simulation was made on rooms facing north and south to determine the temperature of the spaces when the building is oriented properly to face the south façade.

Fig 3.4 https://doi.org/10.3389/fbuil.2016.00003



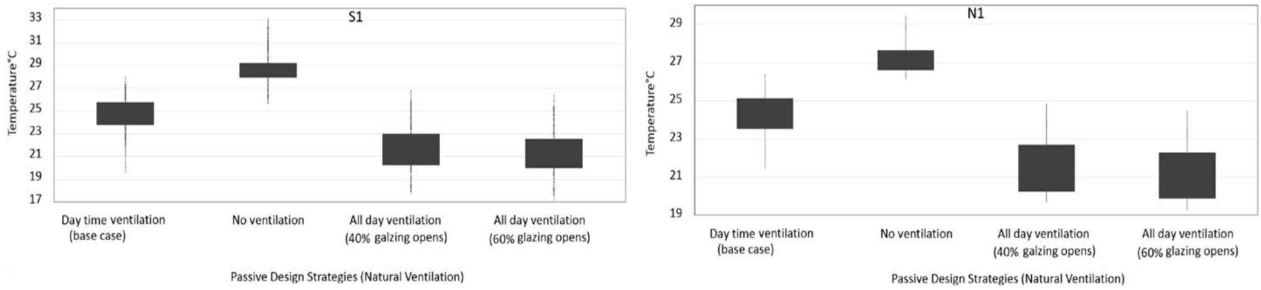
The main purpose of using shading devices is to prevent direct solar radiation from penetrating the external walls. There are various kinds of shading: shading of the building over itself; as a facade design shading using overhangs, fins and blinds; and shading of surrounding buildings and far obstacles.

Fig 3.5 https://doi.org/10.3389/fbuil.2016.00003



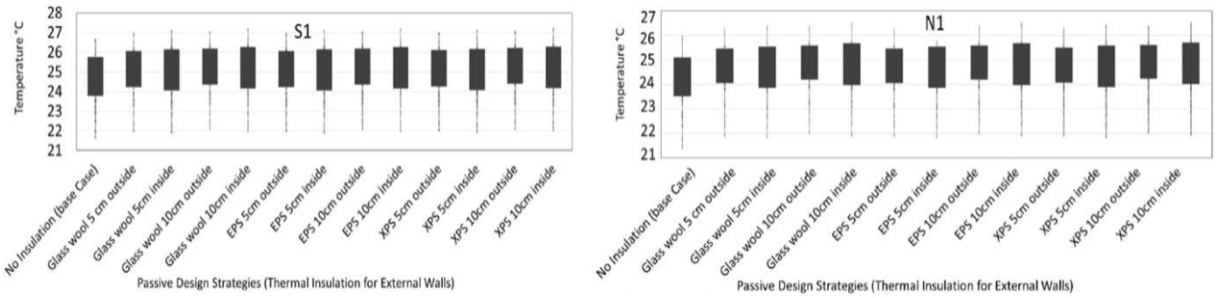
Shading devices with various dimensions were used, to determine the best shading dimension to use including overhangs and blinds, and combining both overhangs and side fins, in order to analyze the effect of them on the indoor air temperatures. Increasing the air movement rate in indoor spaces increases the cooling efficiency in hot and warm seasons. Natural ventilation is one of the passive design strategies, which enhances indoor air quality in hot and dry regions by providing fresh air. Night ventilation and evaporative cooling are some of the important ventilation strategies used to decrease the indoor air temperatures in hot and dry regions

Fig 3.6 https://doi.org/10.3389/fbuil.2016.00003



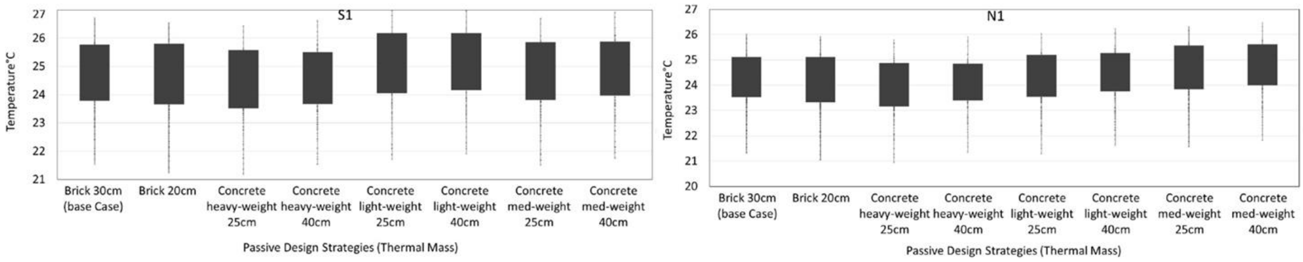
Appropriate insulation material helps to reduce undesirable heat losses or heat gains through the building envelope. It decreases the heat flow rate through the wall, roof, floors, and openings, whether outward or inward, and as a result, reduces the energy consumption of the building (LHSBC and Guido Wimmers, 2009; Autodesk Ecotect Analysis, 2013). Thermal insulation materials have an impact on the indoor air temperatures of the buildings. A well-insulated building results in lower conductivity through the building envelope fabrics, decreasing the heat flow as well as providing a comfortable indoor environment. The amount of heat loss from building components is measured by *U*-values or thermal transmittance. A lower *U*-value means lower heat loss through the building fabrics and better insulation of the buildings. In addition, *R*-values or thermal resistance is a measure of a material's resistance to heat flow, and therefore, an indicator of a material's insulation properties. It is the inverse of the *U*-value (LHSBC and Guido Wimmers, 2009). In this study, different insulation types, with various thicknesses, were employed in the external walls as well as in the roof separately, to examine their effects on the *U*-value of the building, and as a result, on the indoor air temperatures. The thermal insulation materials used in the simulation modeling were based on recommendations by the INBR and are the typical insulation materials mostly used in Iran (Ministry of Housing and Urban Development, 2009; IFCO, 2012; IRIMA, 2012).

Fig 3.7 https://doi.org/10.3389/fbuil.2016.00003



Thermal mass is the capability of fabrics to save heat. It can be integrated into a building as part of the buildings' components in the walls and floors. High thermal mass materials' such as concrete, brick, stone, and earth, can absorb and hold heat, and release it slowly later on when there is a temperature difference between the material and the surroundings (LHSBC and Guido Wimmers, 2009). It is suggested that high thermal mass materials should be used in building components in hot regions, as this provides a comfortable indoor environment by reducing the indoor air temperatures and avoiding overheating (Kasmai, 2008). Based on Kruger and Givoni (2008), using high thermal mass materials in external walls reduces indoor air temperatures, especially when considering night-time ventilation for the room. In this study, various thermal mass materials with different thicknesses were applied to the simulation model. Table 7 shows the materials applied to the base case external wall components.

Fig 3.8 https://doi.org/10.3389/fbuil.2016.00003



4. DISCUSION

To estimate the effect of the optimum design solution, the measured indoor air temperature of the case building was compared to the effect of each optimum factor on the indoor air temperatures. Based on the results of the field study and the simulation analysis, by using passive design strategies, an optimum design solution for the case building was defined. The optimum factors were taken from the analyzed passive design strategies, including orientation, shading devices, thermal mass, natural ventilation. The optimum passive design strategies were selected based on the effects of them on the indoor air temperatures, which were closer to the maximum comfort band in the warm season. The suggested primary optimum design solutions included suggested building orientation a combination of 30 cm of the overhangs and side fins for south- and north-facing side classrooms, external thermal insulation material with the *U*-value between 0.28 and 0.32 W/m2K for the external walls, 5 cm thermal insulation on the inner side of the roof, 25 cm high-density concrete blocks as a thermal mass for the exterior facades and all-day natural ventilation strategies during the warm season (Optimum 1). In addition, 30 cm outer brick was considered as a second suggested thermal mass material along with the other options used for the optimum design solution 1 (Optimum 2).

The aim of the optimum solution was to reduce the indoor air -temperatures in the warm season and to keep the internal temperature in an acceptable range within the minimum energy use. The result of the simulation analysis of each parameter indicated that all-day natural ventilation and the application of the shading devices to the window areas helped significantly in reducing the indoor air temperatures in warm spring season. Employing the 30-cm overhang and side fins on the windows is the suggested optimal projection to reduce the indoor air temperature in spring.

Applying 5 cm of thermal insulation on inner side of the roof also helps to decrease the indoor air temperatures in the warm season. Although adding insulation materials to the external wall increased the indoor air temperatures in spring, they had a small impact on increasing the temperatures, which was overcome by applying the shading devices and an all-day natural ventilation strategy. It should be noted that all-day ventilation has no cost at all and only obtained by keeping the windows open all day long. The installation of thermal insulation as well as shading devices require installation costs, but using these strategies will reduce the buildings energy costs over the years.

Fig 4.1 https://doi.org/10.3389/fbuil.2016.00003

Passive strategies	Solution	Current practice in the base case
Orientation	South–South East	South
Solar shading	30 cm overhangs and side fins (can be movable to get the effect of sun in winter) Blind and slate can be used in warm season	No solar shading
Ventilation	All day natural ventilation in hot and warm seasons	Natural ventilation from 7:00am to 21:00 in spring
Wall insulation	10 cm common thermal insulation material on external side of external walls layers	No wall insulation
Roof insulation	5 cm common thermal insulation materials on internal side of roof layers	5 cm insulation on the external layers of roof
Thermal mass	25 cm high-density concrete blocks or 30 cm outer bricks in external walls	30 cm brick in external walls

5. CONCLUSION

The aim of this study, generally is to improve the cooling /comfort in hot climate (Cyprus) in terms of passive solar design, and educating people on how effective this approach can be in conserving energy in living spaces. This study was carried out to investigate the thermal performance of a school dorm in Cyprus during a warm spring season. A series of field studies, including field measurements, were conducted to predict the indoor thermal condition, as well as the occupants' thermal comfort. Thermal simulation analysis was also performed to evaluate and improve the building's thermal performance using passive design strategies. the base building was modeled in a dynamic building thermal simulation tool called Design Builder. Based on the passive design strategies and the students' thermal preferences within the rooms, the optimum design solutions were defined for the buildings to improve the indoor thermal conditions. The suggested optimum design solution includes all-day natural ventilation, installation of overhangs and side fins, the use of thermal mass and thermal insulation in the external walls and the roof, as well as the orientation. The study shows that the application of passive design strategies, including south and south-east orientation, 10 cm thermal insulation in wall and 5 cm in the inner side of the roof, the combination of 30 cm side fins and overhangs as solar shading devices, as well as all-day ventilation strategy and thermal mass materials with 25–30 cm thickness, has considerable impact on reducing the indoor air temperatures in the warm season in Cyprus.

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