From Tradition to Modernity:
Innovative shadings to save energy in residential architecture of Bodrum, Turkey

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Abstract

There is much to be learned from traditional buildings while improving them for contemporary needs. With the change of climatic, structural and physical conditions of buildings as well as inhabitants with different life styles, energy consumption in such buildings have increased. At the same time, contemporary buildings are being built generally without traditional principles and without attention to efficient energy use. In the current concern for sustainability, there is a pressing need to develop and install shading devices that can help transform them to energy efficient buildings.

This paper presents innovative architectural shading ideas for reducing the energy demand of the residential buildings in Bodrum developed using building energy simulations. First, a traditional house in Bodrum has been analysed from the point of view of energy consumption. Then a prototype house has been developed according to the simulation results of the reference objects. Local, window, and roof shading elements have been developed for this prototype in order to measure the energy reduction effect. As a conclusion, their effects on energy saving has been described and the potential of introducing the shading devices in the new buildings has been discussed.

Keywords: Shading, energy simulation, Mediterranean climate.

Nomenclature

a	annual
k	thermal conductivity W/Mk
kW	cooling/heating load
N	hourly air change rate ac/h
Rs	solar radiation W/m^2
U	thermal resistance W/ m^{2}K

Abbreviations

BBH	Bodrum basic house
MZ	Mezzanine house
MZ_{act}	Mezzanine house actual
MZ_{opt}	Mezzanine house optimized
SHGC	Solar heat gain coefficient
U_g	U value of the glass
U_r	U value of the roof
Uw	U value of the external wall
WWR	window to wall ratio
XPS	extruded polystyrene

Introduction

Within the paradigms of sustainability, eco-designs and green buildings, energy efficiency has become central in the architecture of the contemporary world. One of the most cost-efficient and eco-friendly ways to deal with the energy issue in buildings is "solar shading". However, many buildings are still being constructed without appropriate shading devices, while many traditional buildings continue to remain without improved, appropriate shading devices. In Mediterranean Architecture, the vernacular buildings in Bodrum are notable as being in need of thermal protection from such solar shadings. In a recent study, an effort has been made to test and analyse potential shading devices so that they can be employed to improve such vernacular buildings, to be developed as appropriate for the contemporary needs.

Many researchers have often demonstrated basic and simple ways by which architecture can be fashioned for energy efficiency. Hassan Fathy (1986) for example, has shown that buildings could be oriented at specific angles from the North according to locations, in order to produce appropriate means of self-shading. Similarly, Nagy et. al. (2000) demonstrates that solar heat gain can be significantly reduced by architectural shading, while Nasrollahi (2010) explains the effects of various shading measures in order to reduce the cooling load. Furthermore, Laouadi et. al. have presented the effects of solar shading even in cold-climate houses (2009). In fact, the importance of managing the exposure to sun and how to deal with it has been a central issue in architecture even during historical times. For example, Vitruvius on his "Ten books of architecture" says that whatever nature exaggerates will have to be restored by art. As Rowland et. al. (1999) writes, Vitruvius suggested different orientations according to the exposure to sun. Socrates designed his "solar house" with a projected roof, which allows using winter sun and avoiding the solar radiation on the south facade during the summer periods.

Taking these further, I have argued in my Ph.D. thesis that,

> "From the building mass to the smallest building element, each factor has a direct influence on the energy consumption of a building. Upgrading the thermal characteristics of these factors can reduce the amount of consumption significantly."
> Karasu, 2010: 4

This paper is an extension of this argument and attempts to present the benefits of solar shading components in vernacular architecture, to be introduced as a contemporary necessity. It takes Bodrum as a situation in which this can be demonstrated given its climate and the presence of un-shaded vernacular buildings. The paper will present first the geographical and climate characteristics of the region of Bodrum. It will then discuss the vernacular urban structure and architecture briefly. This will be followed by an analysis of energy use in a traditional house from which a prototype has been developed to test the possible shading devices with regard to local, window, and roof shading concepts. The analysis is based on computational building simulations which have been run by the software "Designbuilder V 1.8", that provides a range of environmental performance data including outcomes of solar shading.

Bodrum: the study area

Bodrum is a small resort town located on the south-eastern coast of the Aegean Region in Turkey, where the vernacular urban and architectural patterns provide helpful hints about shading to design energy efficient environments. Its geographic location presents several advantages for the extensive use of passive architectural measures. Bodrum is a typical Mediterranean city, which experienced a construction boom in the recent years because of the huge growth in local and international tourism. Unfortunately, the thermal quality of the buildings has been neglected by the owners as well as builders.

Figure 1. Geographical position of Bodrum

Lemke et.al (2008) point out that the energy consumption of a building is strongly related to the climate surrounding it. Turkey's geographic location is disadvantageous in this sense because of strongly varying summer and winter conditions which complicates the development of simple design solutions with regard to better comfort conditions and energy efficiency.

According to the Meteorology Department of Republic of Turkey, the Aegean coasts of Turkey display a typical Mediterranean climate of hot summers and mild winters. Characteristics of local climate in Bodrum do not show significant differences from the common characteristics of Aegean-Mediterranean climate. Some important aspects are:

- Hot summers and moderately cold winters.
- Intense heat in the day-time in summer.
- Often intense cold at night in winter.
- Minimal annual rainfall with very high summer aridity.

These climatic values show the enhanced importance of solar shadings required in the buildings in Bodrum. In fact, site planning, orientation and formation of buildings, vegetation, interior ventilation, and the appropriate use of building material become important given these specific characteristics.

Temperature °C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Max.	15	15.1	17.4	20.9	25.9	31.1	34	33.7	30.2	25.6	20.1	16.3
Average Min.	8.2	7.8	9.4	12.5	16.4	20.6	23.2	23.1	20.2	16.6	12.6	9.6
Max in summer						**42.3**	**44.2**	**45.0**				
Min in winter	-1.6	-4.5										0.2

Table 1. Temperature Values for Bodrum according to Turkish State of Meteorological Services 1978-2008: Temperature values of the summer period indicate the importance of the architectural shading in order to avoid direct solar radiation.

Vernacular architecture in Bodrum: Vernacular urban structure

In the traditional Aegean cities like Bodrum, streets have a homogeneous organic structure, which enables an inherent shading effect. The width is the main parameter for the amount of direct radiation received from the streets. Narrow streets enable mutual shading from the horizontal elements. Besides typical Aegean architecture, Bodrum has its own characteristics of vernacular architecture. The difference can be seen in public spaces, which are being used as the front gardens of private houses. Indoor gardens, bordered with facades and low walls of narrow streets are usual transitional locations of private spaces to public spaces. The site occupancy index in Bodrum is 0.1[1]. Therefore, this characteristic of the public spaces has been protected to the present.

The settlements in the city center of Bodrum however have been developing since the 1950's-60's, and most of them are exposed to excessive sun because of the wider streets. Moreover, the tendency of the new settlements has been towards constructing single-family houses in groups or separately. One of the most important points of housing settlements in Bodrum is that the new units have been built directly beside the old units in the same parcel of land. This means that the settlements have expanded inwards. Therefore, although the use of city spaces did not change between 1959-2000, the city density has increased (MOB, 2006).

In figure 2, the density of the buildings and the range and effects of the shading can be seen very clearly. The illustration on the left is from an older vernacular settlement with narrow streets. The illustration on the right is an example of the settlements after 80's which have been developing primarily to facilitate tourism, and has deviated from this traditional form.

Figure 2. Illustration of the shading effect of built structure in Kumbahçe region of Bodrum (Not to scale). On the left, old patterns in the city centre. On the right, the settlement patterns of the tourism era. Note the differences between the shading affect through streets and the densities of the buildings.

[1] The site occupancy index is the ratio of the permissible coverage to site area

Vernacular residential homes in the city

According to the Encyclopaedia of Vernacular Architecture of the World (Oliver, 1997), Turkey lies in the IV2 zone, called “Caucasus Peninsula”. Nevertheless, Bodrum should be in the IV6 zone, which is called “Insular Mediterranean”. The city shows typical characteristics like the settlements in Cycladic islands, which are in the IV6 zone.

The most common type of the vernacular dwellings in Bodrum is the Mezzanine house. Unfortunately, they can be counted on the fingers of one hand. The house was rectangular in shape (Kazmaoglu, 2004) (Figure 3 & 4). The interior size without thickness of the walls was approximately 3.2-3.6 meters on the short side and 5.5-6.0 meters on the long side. This proportion seems to have been used as a common rule for many elements, because we see this proportion at windows and doors too. The narrow dimension of the rectangle depended on the floor of the mezzanine or the possibilities afforded by the roofing material.

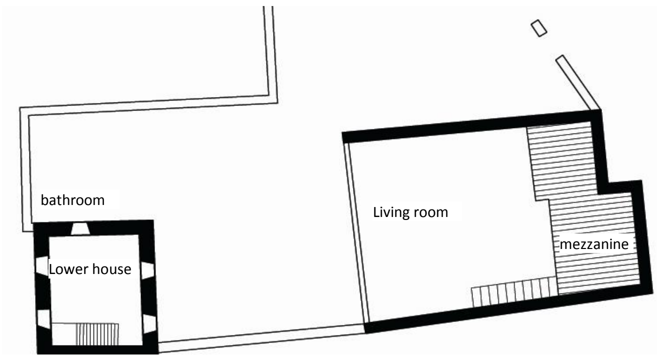


Figure 3. Plan of the Mezzanine House (Author)

There is usually a stove in the middle of the wall forming the short side of the rectangle nearer to the door. This part of the house, referred to as the “lower house”, is used as a kitchen. Inside the wall in the corner of the house nearest to the stove is a small bathroom (re-placed after restoration under the mezzanine).

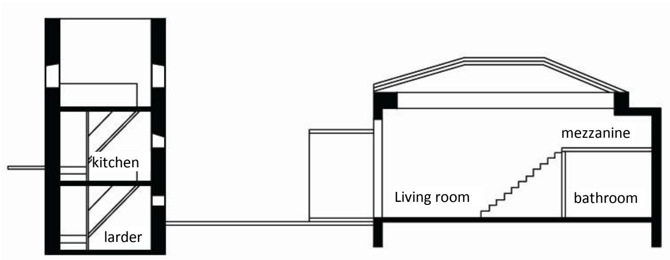


Figure 4. Section of the Mezzanine House (Author)

The living room with a ceiling height of approximately 300cm is reached by means of staircase next to the front door. The area immediately underneath the kitchen is used as a larder and grain store.

Within the framework of this layout, ceiling height in various spaces is in keeping with their functions, being 2.5-2.8 meters in the kitchen and entrance section of the “lower house”, and only a strictly necessary 1.6-1.8 meters in the mezzanine. The living room has the highest ceiling; approximately 3 meters. Due to the variation of the ceiling height, natural air ventilation can be facilitated.

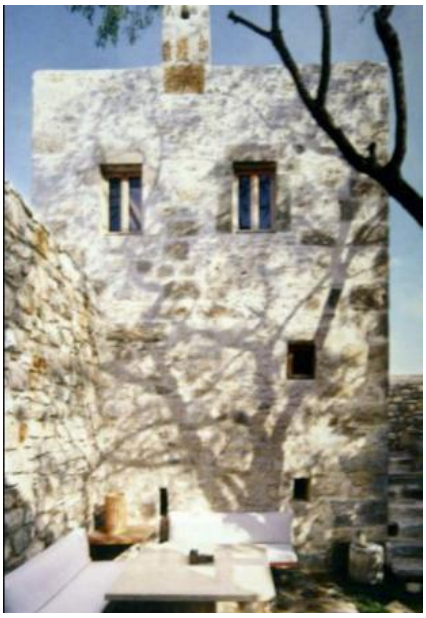
Thermal simulation analysis

The mezzanine house described above will be analysed according to the building’s thermal simulation results. These simulations have been run as part of a doctoral studies under the title: “Concepts for Energy Savings in the Housing Sector of

Bodrum, Turkey: Computer based analysis and development of future settlements using renewable energy" at the Technical University of Berlin (Karasu, 2010). They have been run for a whole year to see the contradictive effects of shadings elements on the heating demand. Furthermore, the prototype house, which will be described in the next section, has been analysed, too. The design of the shading elements for this prototype has been developed for the period May-September, where cooling energy is necessary for comfort standards in Bodrum. Standard values have been used for other criteria, which have an influence on the energy efficiency of the building.

Mezzanine House as an example of vernacular architecture

In this section, the simulation results of a Mezzanine House (MZ) is evaluated to determine if this traditional type of dwellings can be an alternative to be used in the future settlements. First, it has been simulated in the actual condition and then with optimised energetic parameters.



Picture 1. Mezzanine House (Author)

The external walls of the MZ under study, which has a floor area of 35 m^2, are constructed of 80 cm thick stone structure. In the optimised version, 8 cm thick XPS insulation[2] is applied with appropriate finishing material to the inside of the wall. It was decided to apply insulation material to the interior, because the stone texture view from outside should be kept in terms of architectural traditions. A Mezzanine House traditionally has a wooden floor and roof structure. Both actual and optimised versions have the same insulation material placed on the roof; glass wool with a thickness of 15 cm.

Furthermore, single glazed windows with six mm thick clear panes, are exchanged for triple glazed windows. It should also be considered that these traditional houses have a small WWR ratio. The WWR approximates to four per cent for eastern and western walls, and three per cent for the south wall. The north wall has no opening. These small ratios affect the heat loss-gain through glazing significantly. They are beneficial in terms of energy saving through decreased heating and cooling demand. On the other hand, artificial lights required due to insufficient natural illumination will increase the energy demand.

The results below show that the vernacular building has a significantly high energy demand. Although it is possible to reduce the energy consumption for both heating and cooling through passive architectural measures, such as improved insulations, the values reached through insulation alone are not satisfactory. These points to the need to improve energy consumption through other means, for which purpose a prototype is designed with as many solar managing devises as possible.

[2] Please see the abbreviations at the beginning. XPS stands for Extruded Polystyrene

House	Cooling Energy Demand		Heating Energy Demand		Total Energy Demand		Heating Load	Cooling Load
	MWh/a	kWh/m²a	MWh/a	kWh/m²a	MWh/a	kWh/m²a	kW	kW
MZ_{act}[3]	2.36	33.11	6.22	86.98	13.68	182.86	6.33	12.0
MZ_{opt}[4]	1.59	22.27	2.6	36.85	5.5	77.38	2.23	6.16

Table 2. Energy Values of the Mezzanine House

Furthermore, the energy analyses also prove that, neither the actual vernacular houses nor the optimised condition of them through insulations can provide for the basic requirements of energy efficiency and comfortable living spaces in Bodrum. Beside all other factors, climate change has also a significant influence on this fact. As Otto et.al (2001) have noted, a prototype is a representation of a design idea, which is taken through an improvement process.

Prototype house for Bodrum

Dimensions		m²
total floor area		114.7x3
conditioned area		99.7x2
conditioned volume		279.16
roof area		99.7
Window area E/S/W/N		1.5/16.8/1.5/3.6
Envelope		U: W/m²K
window	Ug	0.78
	SHGC	0.47
external wall	Uw	0.20
roof	Ur	0.33
Air tightness N		ac/h
air leakage		0.6

Table 3. Dimensions and thermal characteristics of the prototype

In order to accommodate above factors, a prototype house, called Bodrum Basic House (BBH) has been developed to define the energy-efficiency standards for the dwellings in Bodrum, where solar shading components have been made an important part of it.

A two-unit house with 100 m² per unit has been designed as the prototype. Based on the municipal regulations for Bodrum, the BBH has two stories. Every unit has 50 m² on each storey, which makes the total area of the two unit prototype 200 m². However, it is not loaded with sophisticated new technologies, which are extremely expensive and are out of reach for the locals. The idea is to use existing materials in the region with existing or new yet compatible concepts.

Figure 5. Energy efficient prototype for Bodrum

[3] MZact stands for the actual condition of the mezzanine house without any energy saving measure.
[4] MZopt stands for optimized condition of the mezzanine house with passive architectural measures

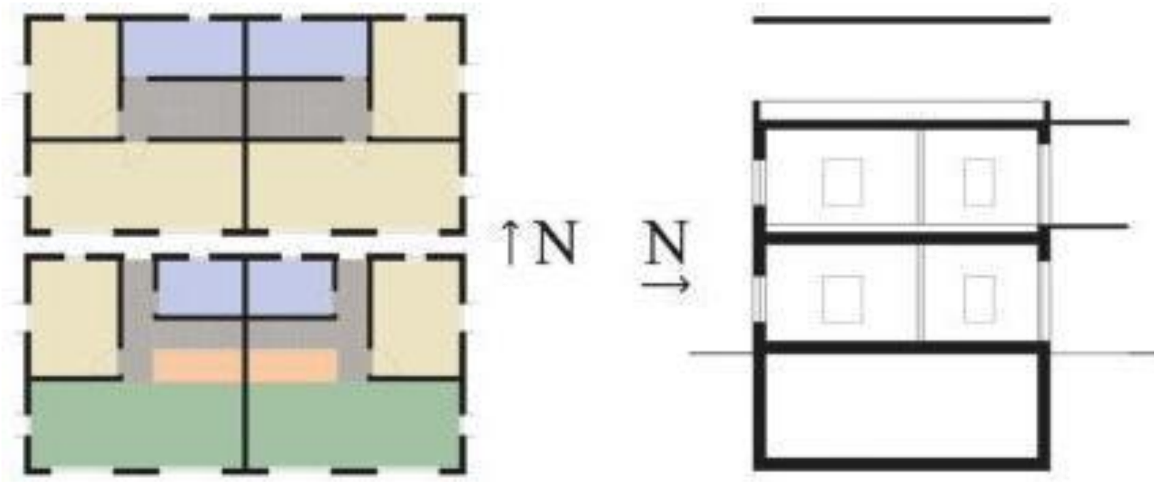


Figure 6. Plan and Section of the BBH; yellow: bedroom, blue: bathroom, grey: circulation, orange: kitchen, green: lounge

Solar shading for less cooling energy demand:

As in the case of Bodrum, or in other regions with hot summer periods, shading strategy plays an important role in energy saving by reducing energy demand for cooling. It is also an eco-friendly and economically efficient measure. Therefore, window, local, and roof-shading elements have been developed for the prototype. Simulations have been run for these three architectural elements separately: Each of these elements has been simulated according to their own shading strategy, which is discussed below.

Local shading components

Local shading elements have been widely used in many vernacular buildings. As masonry walls were the popular method of the construction of vernacular buildings in Bodrum, Jambs for the openings were typical building elements in them. Beside their function as a frame for windows and doors, they have been used as overhangs for shading. Nevertheless, they have been built randomly. These opaque exterior shades, which block beam radiation from entering windows, have been simulated in terms of form, position, and thickness.

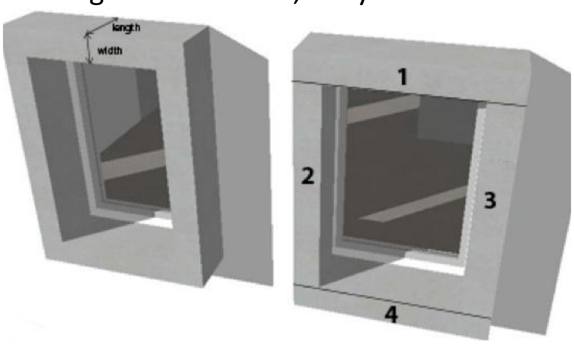


Figure 7. Illustration of Window Shading Elements**:** 1=overhang, 2,3=sidefins, 4=reveal, length=from the wall on, width=thickness of the material

In the prototype, painted lightweight concrete, has been chosen as the material to construct these jambs. This is widely used in Bodrum. Concrete is painted with a light color and has a brushed surface. The thermal conductivity of this material is *k*=0.3 W/mK.

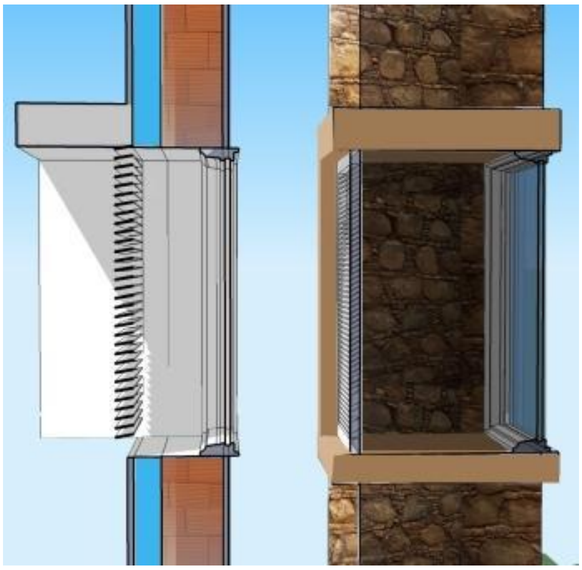


Figure 8. left: section of the BBH, right: vernacular architecture.

The width of the simulated components varies between 8 and 15 cm as well as the length between 15 and 45 cm. Other dimensions are not relevant in terms of energy efficiency or from the point of view of architecture. The shading component is divided into four segments and each of these segments are simulated separately and combined. According to the simulation results, the combination of the segments 1, 2, and 3 with 45 cm length and 15 cm width has the best performance on cooling load. On the other hand, the combination of segment 1 and 2 with 30 cm length and 15 cm width has approximately same values as the combination mentioned above. Both of these variations reduce the cooling load by up to 12 per cent (-5 kW). The traditional quadrate form of shading elements in Bodrum shows a similar performance as the above mentioned variations.

Figure 9. Shading of the south façade with deep eaves

As with the case of the mezzanine house, large external walls are common in vernacular houses of Bodrum. The windows are placed close to the inner wall surface while the thickness of the external walls provides a shading effect to the recessed windows. The sidefins as adopted in the prototype compensate for the thickness of the walls absent in the modern houses and produce the same effect (see Figure 8).

Furthermore, eaves are frequently used in regions like Bodrum. Deep eaves for the south façade let the winter sun and avoid summer sun (Figure 9). The same principle is used in the prototype in created cantilevers which act as a shade as well as a balcony. Larger windows on the south façade, or on facades with sea-view can be seen often in the region. Therefore, elongated balconies above the first floor and an eave with the same principle above the second floor are used in the prototype to accommodate the architectural needs while providing for energy efficiency. It is suggested that they can be introduced in the modern buildings in the Bodrum.

Window shading components

Figure 10. Window shading of the prototype (left) and the mezzanine house (right)

According to the existing research of the *"Low Energy* Architecture Research Unit" of the London Metropolitan University, internal shading elements such as Venetian blinds or curtains are thermally ineffective for summer (Learn,2010). Nevertheless, simulations were run to determine their impact on the cooling load of dwellings in Bodrum. Window shading elements like blinds and rolls were also simulated for both the inside and outside locations of windows. The choices for shading control types were as follows:

- For summer: shading is used at night and during the day, when the solar radiation incident on the window exceeds the set-point Rs: 120 W/m².
- For winter: shading is used when either the heating is on at night, or when off during the day.

Simulation results show that shading elements in the form of venetian blinds reduce the cooling load by 0.5 per cent if they are placed inside, and 1.5 per cent outside the window. As can be seen in figure 11, a combination of local shading and window shading elements has the most energy efficiency.

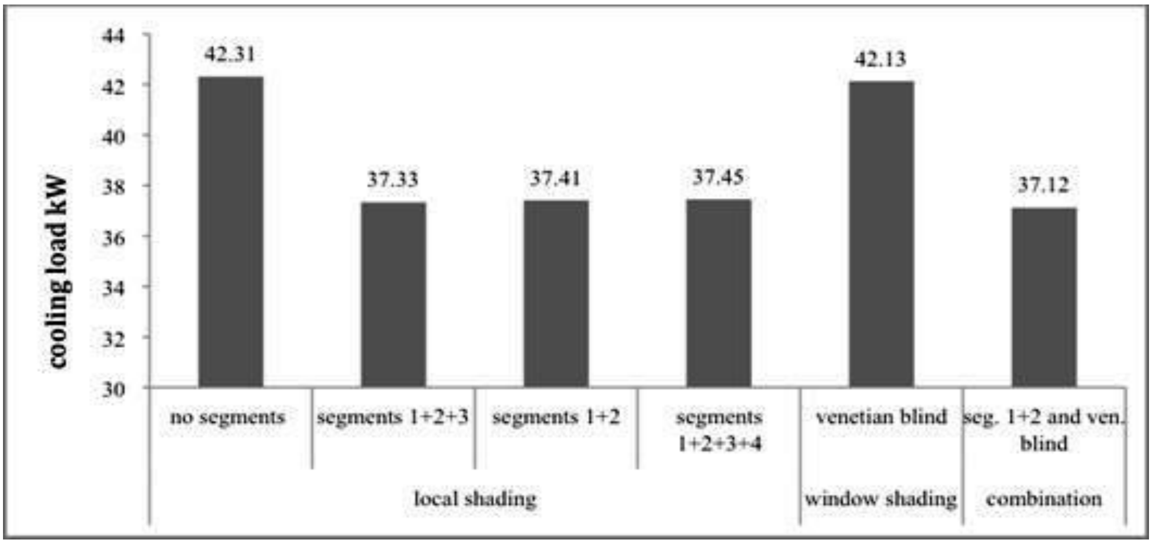


Figure 11 Cooling Load (kW) Performances of the Simulated Window Shading Elements

Roof shading

The other important factor which has not been considered in Bodrum yet is roof shading. In the study, roof shading elements were simulated to evaluate their benefit. Due to the anticipated positive effects of roof shading elements, design studies on these elements are presented in this section.

Simulations have been run on roof shading elements in order to prove their contribution to reducing the cooling load. Several designs have been tested distinguished by their shape and coverage area. Furthermore, operative roof shading elements, which may be beneficial, have been tested as well.

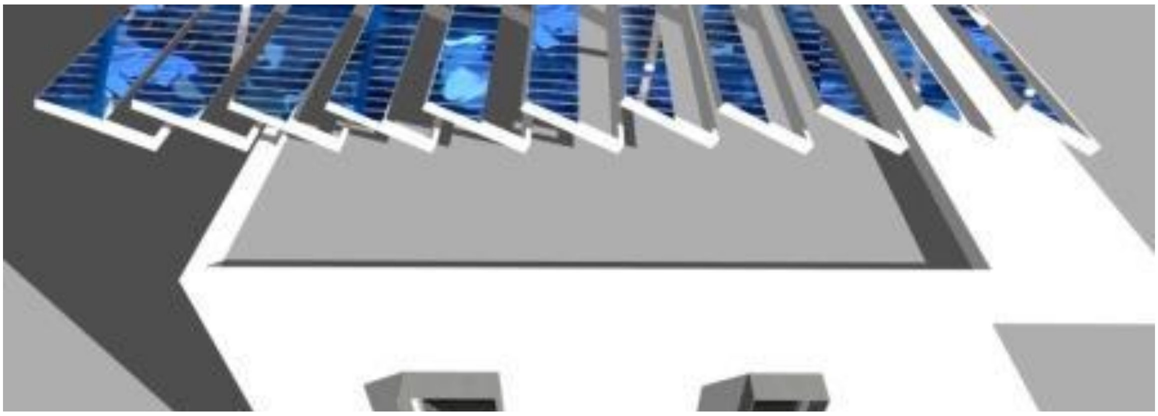


Figure 12 Photovoltaic integrated roof shading components, which allows winter sun

Canvas and trellis with growing vegetation has been chosen as covering materials for the roofs because of their widespread use in Bodrum. An average transmittance value of about 50% for trellis with vegetations and 80% for canvas, has been used by the simulations. Furthermore, shading components allowing the use of solar panels were a part of the analysis.

According to the simulation results, the roof shading of a house in Bodrum can reduce the cooling load by up to 15%. The reduction of the cooling load of the second floor is up to 25%, whereas it is 2% for the first floor. The heating load can be reduced by up to 10% as well.

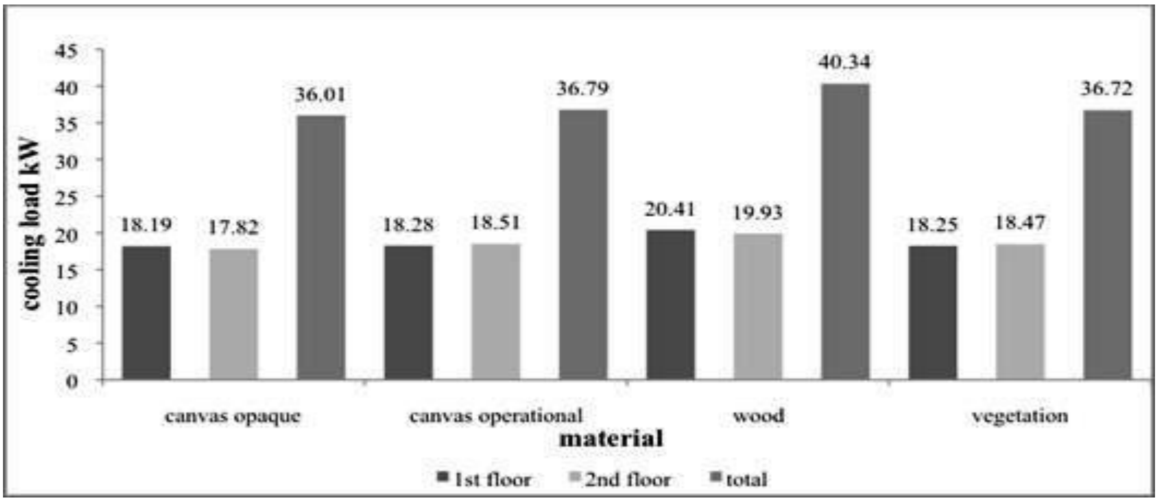


Figure 13 Effects of the Roof Shading Material on the Cooling Load

Moreover, opaque shading elements perform 2% better than operational systems. Furthermore, simulation results show that area-wide shading elements have the greatest energy efficiency. In terms of materials, lightweight elements such as canvas and natural vegetation perform up to 10% better than wooden elements. Heavy weight elements are not recommended due to their high thermal mass character.

Conclusions

According to the simulation results, vernacular architecture does not meet thermal requirements of an energy efficient building as defined in the contemporary society. Nevertheless, it provides useful hints which can be developed for future settlements.

The roofs and windows of houses in Bodrum should be protected from intense solar radiation during the summer period. The roof area of the vernacular buildings has been kept small because of construction reasons. Therefore, solar shading was not necessary. However, the roof areas are nowadays significantly bigger. A comparison of the mezzanine house and the prototype presents the clear difference. Therefore, the roofs should be shaded. Simulations proved this fact: Roof shading as a single measure can reduce the cooling requirement between 1-25.3% depending on the energy characteristics of the house, whereas it is more efficient in non-energy-refurbished reference object.

Furthermore, window and local shading components combined has more influence on the cooling requirement. 13.4% of the cooling requirement by the prototype can be reduced in this way. This percentage is approximately three times higher in non-refurbished buildings. Such components should be designed carefully in order not to increase the energy demand for lighting. In vernacular buildings, they are designed or constructed according to a rule of thumb. Jambs around the windows were not made with specific needs of the situations and were not energy efficient. Similarly, small window shutters led to enhanced energy consumption for lighting. Nevertheless, the placement of windows close to the inside surface of the external wall can be adapted to new buildings. The thickness of masonry walls of the vernacular buildings can be provided by extended sidefins and overhangs. To provide optimised balance between the reduction of the thermal energy requirement and lighting energy, they should be designed for each particular building.

Roof shading elements in combination with window and local shadings can reduce the cooling load by up to 49.4%. However, they should be removable or specifically designed to allow the winter sun to penetrate the building to avoid increased heating load.

In conclusion, this paper demonstrated that much can be learned from vernacular buildings of Bodrum to help design the contemporary buildings there although the vernacular buildings by themselves are not energy efficient. The simulations done and presented in this paper has illuminated the ways in which the shading devices can be introduced in the modern buildings adopting ideas and attitudes of the vernacular buildings. It will also help re-furbish the vernacular buildings for more efficient energy use. On the whole, the study confirms that purposefully and specifically designed shading elements for the buildings in Bodrum can make a significant contribution to the energy savings and help contribute to the production of climate-responsive buildings and sustainable settlements.

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