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RESEARCH ARTICLE

CONTEMPORARY SAUDI HOUSE FORM AND SUSTAINABILITY MEASURES

[1,*]Shams M. Alshamasi and [2]Nigel Westbrook

[1]College of Engineering, Prince Mohammad Bin Fahd University, Saudi Arabia
[2]School of Architecture, Landscape and Visual Arts, The University of Western Australia, Australia

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ABSTRACT

This paper investigates the design deficiencies in the current Saudi house. It sheds light on the socio-cultural and climatic responses that should be offered by the physical form in order to enhance its passive performance and reducing the reliance on mechanical cooling. A typical size of a common design of a domestic unit is analysed. The analysis identifies the main design deficiencies which contribute to extensive reliance on mechanical cooling. Recommendations to improve the current design are set up.

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INTRODUCTION

Saudi Arabia has witnessed a radical change in the social, economic and environmental sectors as a result of the economic growth that has accompanied the expansion in production and the exportation of oil, and the rise in the price of oil per barrel relative to gross domestic product (GDP). In referring to the Gulf countries, including Saudi Arabia, Al-Ibrahim states "…in less than a half century, these countries have been transformed from a nomadic and subsistence farming economy into a modern urban/industrial society with per capita incomes that are among the highest in the world" (Al-Ibrahim 1990, p. 64). One of the obvious changes appears in the transformation of the Saudi Arabian built environment. In less than fifty years, the old traditional fabric has been almost entirely replaced by new contemporary gridiron urban plans. The old houses, which were both climatically and culturally compatible with their surrounding environment and which were built with local materials, have been demolished, and the traditional clustered city plan has disappeared (Al-Hathloul & Edadan 1993; Talib 1984; Abu-Ghazzeh & M. 1997). The image of the city and its houses has changed and new images have emerged. To manufacture these contemporary houses, new methods of construction and new materials have been introduced to the country, such as using reinforced concrete structure and constructing walls from cement blocks. These new buildings and manufacturing techniques have, in turn, brought about high energy consumption. This parallels the trend elsewhere. Asimakopoulos et al. noted that during this period the rapid economic growth and increased population growth in developing countries contributed significantly to the energy consumption especially in the housing sector (Asimakopoulos et al. 2001). Exacerbating this trend, in Saudi Arabia the cheap price of electricity encouraged its high consumption, thus the country is still witnessing an annual increase in power demand of 6%, primarily fuelled by domestic consumption (Alyousef & Stevens 2011). In Saudi Arabia the energy consumption per capita is 6.8 tonnes of oil equivalent (toe) which is four times above the world average of 1.8 toe (Enerdata 2011). Thus, its economy and infrastructure need to be released from a dependence on the oil economy, or economic collapse will inevitably occur. In relation to the subject of this paper, the modern Saudi home is entirely dependent on oil-powered electricity. Future Saudi towns and their houses will need to adapt to the new energy consumption paradigm, notably through adaptation and redesign of residential buildings. Residential buildings in Saudi Arabia consume 70% of their total electricity use on air conditioning (Lahn & Stevens 2011). This electricity is 100% generated from fossil fuel (Mundi 2010). It is predicted to be depleted by 2038 and no alternative energy source is being developed (Lahn & Stevens 2011). Therefore, in order to reduce the consumption of fossil fuel, it is critical that both individuals and the state invest in alternative sources of energy consumption, whether that be

***Corresponding author: Shams M. Alshamasi,**
College of Engineering, Prince Mohammad Bin Fahd University, Saudi Arabia.

solar, wind or nuclear, in order to reduce the use of residential air-conditioning.

MATERIALS AND MEHTODS

A comparative analysis has been conducted between contemporary Saudi house and a traditional courtyard house. The study focuses on analysing a typical size of a common design of a detached Saudi house in the composite climate in the Eastern Province in Saudi Arabia. A typical representative house has been chosen and analysed based on interviews with consultant architectural offices in the Eastern Province in Saudi Arabia. Then, it is compared to the sustainable socio-cultural and climatic qualities which were offered by the traditional house form in order to investigate solutions for the current design.

Traditional house of the Eastern Province: The traditional house of the Eastern Province was a courtyard house. This is evident in the oasis of *Alhasa* and *Qatif* region. They were attached coral stone courtyard houses which created dense clustered settlement. These houses were unique in creating the principle of a climatic hierarchy consisting of a variety of ventilated shaded and open spaces was applied inside the house and affected its physical form. Firstly, there was always a central open courtyard, open to the sky and completely exposed to the weather conditions. Secondly, the semi-open spaces provided partial shade and shelter from the weather conditions by forming a colonnaded passage in front of the rooms. Finally, enclosed full shade interior spaces adapted to weather conditions by opening or closing windows and doors in order to achieve internal comfort (Fig.1). The form offered the occupants the freedom and choice to increase their comfort when needed this was because the form respected the cultural needs by maintaining family privacy, thus allowing control of the micro-climate by opening and closing windows without interfering with neighbour's privacy. In addition, these rooms which were deeply embedded in the plan, were surrounded by shading, and were enclosed by thick insulative walls. These factors made the rooms the coolest zones in the houses. The spatial order gave the occupants flexibility in adjusting to and tolerating different weather conditions. Another important aspect of the traditional house is that the exterior walls were always protected from direct solar radiation by either being attached to the neighbouring house or by the shaded underpasses, called *sabat* which were important common urban space in this region (Fig.2). The *sabat* was a totally protected, shaded street underneath a bridge room and was therefore cool all year. The change of temperature between shaded and unshaded streets caused *sabats* to be breezy. This area was described by locals as the coolest external domestic space and was the location where locals sat and socialised, and their children played, on the hot summer days.

Typical modern Saudi house: A typical modern Saudi house is a single detached house built on a minimum of 500 square meters. It is usually consists of three floors: ground floor, first floor and roof. Each floor area is about 250 square meters. The house is situated in the middle of the plot and surrounded by 2 meters setback from three sides and a 6 meters front setback required by building regulations. The house usually has a full glazed front façade (Fig. 3). All rooms have at least one large window. Double glazed reflective glass is the common type of glazing used (Fig. 4).

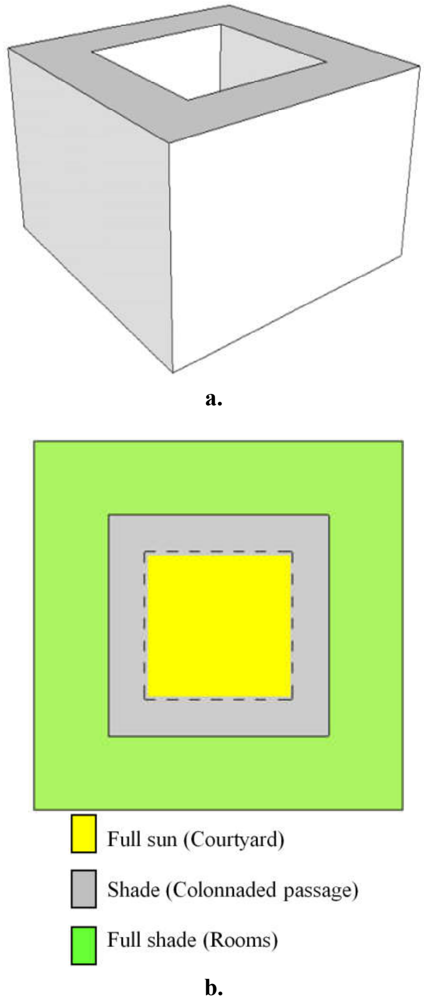
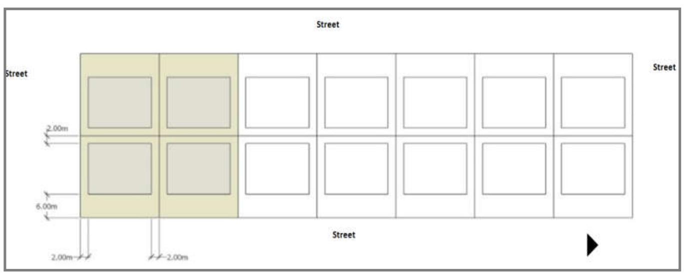


Fig. 1. a. A courtyard surrounded by rooms is the basic form of traditional houses in the Eastern Province. b. Order of spaces from full-sun to full shade gave occupants options to tolerate the weather. (source: the author)

Fig. 2. Shaded streets *sabat* under bridged room between houses contributed to the thermal efficiency of the traditional house. (source: field work by the author)



(Source: the author)

Fig. 3. The common block design in the current suburbs in the Eastern Province

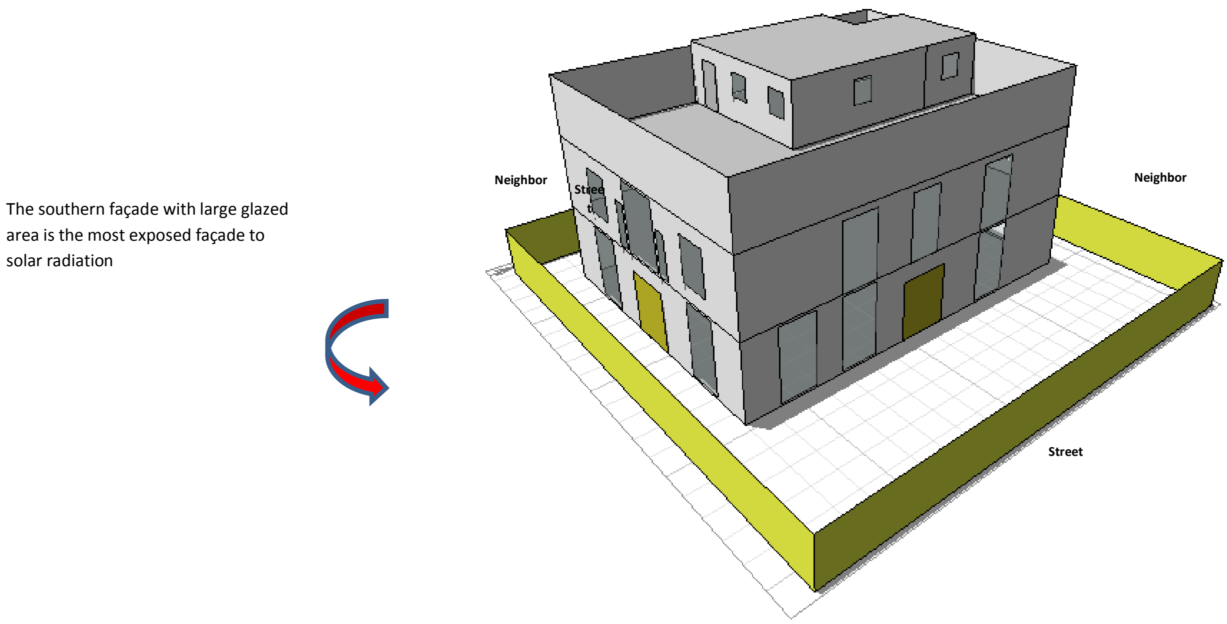


Fig. 4. Large glazed unshaded facades of a typical Saudi modern house. (Source: the author)

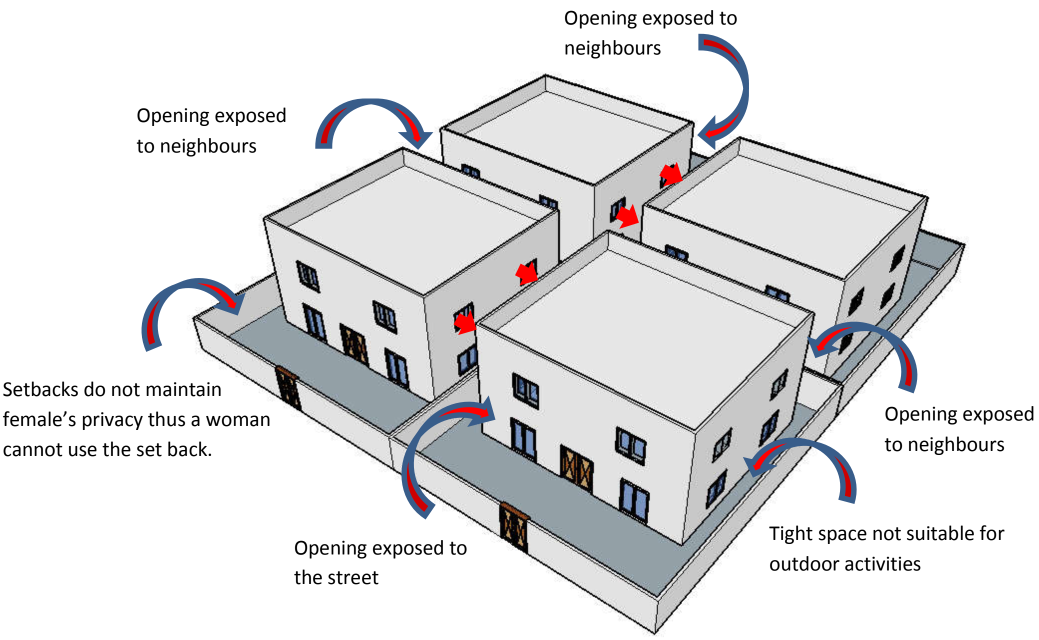


Fig. 5. Privacy conflict caused by box-like detached form and setback spacing (Source: the author)

Sustainable measures of the current design: The current form of box-like detached house has many issues related to climatic and socio-cultural responses that should be offered by the physical form. The contemporary form created cultural conflict that hindered to some extent the passive performance of the house. Firstly, detached box form permits location of windows to be set in the exterior walls. In this socio-cultural milieu the location of windows takes on a different dimension. Permitting windows to be set on the house facades has caused cultural conflicts and privacy issues. Neighbours' windows are exposed to each other and interfere with the family privacy; the rigid inflexible form of the detached house has caused visual intrusion (Fig. 5). The separation of houses and the pattern of subdivision have created contradiction with the main climatic and cultural objectives of windows in such a context. Windows no longer facilitate cross ventilation nor are they designed to deal with visual intrusion as was the case in the traditional house. Large glazed facades have become a distinctive feature of the Saudi modern house (Alsolaiman 2004; Al-Lyaly 1990). In the Eastern Province, the use of full height, unshaded and visually unprotected windows is very common in the main front facades facing the street. Secondly, in the modern subdivision in Saudi Arabia, the contemporary block arrangement has caused houses to be exposed to the maximum weather conditions. In relation to solar exposure, as a result of spacing imposed by building regulations, houses in their detached forms on these blocks are exposed to the maximum surface area of heat from solar radiation, and they are not acting to shade each other effectively. The examination shows that house facades, especially those on the southern and western sides, are exposed to intensive solar radiation, especially during summer days. The facades facing south are exposed to the sun all day. The western façades are in shade all morning while they receive substantial sun in the afternoon. The eastern facades have the inverse situation, as they are in sun all morning and in shade in the afternoon. Additionally, the ratio between building height to streets width (H/W) is not effective in creating shade at thermally critical times during summer days. Facades facing the street invariably fail to benefit from shade as a result of the extremely wide street. Indeed, the shade cast from neighbouring houses is negligible as a result of the building regulation requirement that there be a minimum of 2m site setback from the three sides of the house. The ratio between houses' height to setback indicates that shade will be cast by the house on the setback width rather than on the neighbouring house. This indicates that the required spacing between houses is not effective in providing mutually beneficial shade when it is most needed in the early afternoon when the sun is overhead.

The need for shade: Shade is one of the most effective passive solar control strategies (Olgyay 1963), one which was used extensively in the traditional town and in the traditional houses. In this composite climatic region, the need for shade outweighs the need for evaporative cooling created by prevailing wind. This is because wind in this climatic region is not effective for evaporative cooling most of the time during the year. In addition, it is difficult to orient the existing houses to get benefit from wind at this stage. Thus, to improve the current design of the Saudi house it is critical to implement shade as the main climatic responsive aspect of the built environment. Therefore, the houses' façade should be protected from solar heat by appropriate shading devices. In addition, similar to the traditional openings, the shading element may be implemented in a way to allow occupants to have full control over window. In other words, the shading element should allow occupants to open windows to benefit from the prevailing wind when needed. This could be achieved by making some modifications to the current design.

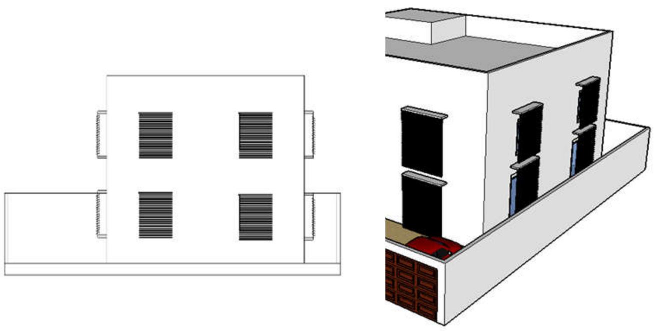


Fig. 6. Vertical windows shade that give privacy, shade and allow full control over windows so occupants can open the window for natural ventilation. This treatment is effective especially for the western windows to prevent from afternoon solar radiation. (source: the author)

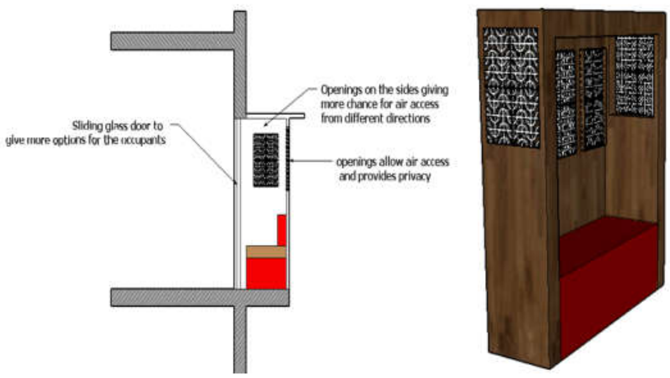


Fig. 7. Retrofitting to current window: *Mashrabiya* with glass sliding door that provides privacy and gives more options to the occupants. (source: the author)

Modifications of Openings: It is important to state here that contemporary Saudi residents are used to the comfort level associated with an air-conditioned environment. In addition, there are times of the year when it is difficult for contemporary residents who are accustomed to a certain comfort level not to use air-conditioning. However, the reliance on air-conditioning could be reduced significantly in some months of the year. Thus, the following treatments do not impose the cessation of mechanical cooling, but they do give more options for the occupants to tolerate the weather without the mediation of mechanical cooling. This is considered as a step forward toward the objective of reducing reliance on mechanical cooling system which is one of the main goals of this paper. The aim of the modification is to preserve culturally appropriate privacy, thus increasing control over windows to be opened to achieve passive cooling when needed. The contemporary domestic building form is an extroverted detached box form, the consequence of which is that full control of opening windows to benefit from ventilation is limited because of the cultural concerns for privacy of women. A solution is therefore required that will provide privacy as well as increasing control of window operating in order to manage comfort levels and to encourage air-circulation. The types of opening treatments are primarily classified here in relation to first floor treatments and ground floor treatments, and could be achieved by implementing the following:

Vertical shading element: The optimal solution to be found in such extroverted form in a similar culture is the use of screened openings that are the practical equivalent of *mashrabiya*, screened openings that were efficient in providing privacy, shade and encouraging air circulation by permitting the opening of windows while screening the occupants within (Fig.6). The *mashrabiya* was used very widely in the facades of the traditional houses in the western region in Saudi Arabia. In the modern era such functional and cultural purposiveness has been neglected. Thus, whereas the *mashrabiya* was used both for aesthetic and functional purposes, its effect could be achieved by contemporary architecture, with the same cultural and environmental benefit. Indeed, there is a possibility to use *mashrabiya* or technologically equivalent screening in the current houses to maximise comfort (Fig.7). This element could be installed as a projection on the first floor facades, as applied to currently existing openings. In contemporary houses the sliding window glass may be kept for better weather control. In case of full-height windows, *mashrabiya* could be used as a seating area (Fig.8).

Bridging shading element: This treatment was inspired by the *sabat* in the traditional town. In this type of treatment, there are three possibilities that could be applied: the first possibility relates to openings on the ground floor this requires the installation of a horizontal shading element extended from above the opening to the fence (Fig.9). The second possibility relates to openings on the first floor. In this case the bridging shading element would be extended from above the window to the opposing neighbour's window (Fig.9). In both cases the shading element may be controlled manually or electrically so it could be extended or folded to tolerate weather conditions. This strategy has the advantage of providing shade to the setback area as well. The third possibility is implementing a bridged room. This bridged room may be a connection between two houses. A room is attached to each house, sharing a wall with the neighbouring house (Fig.10). Thus, if this type of treatment is used, there would be a need to address the rules for the property boundaries.

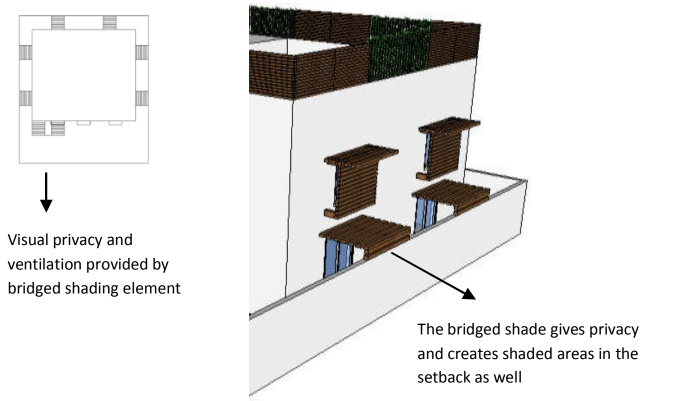


Fig. 8. Adding bridged shading above windows on the ground floor in an existing condition. The shading element has to provide privacy and should allow breeze. (Source: the author)

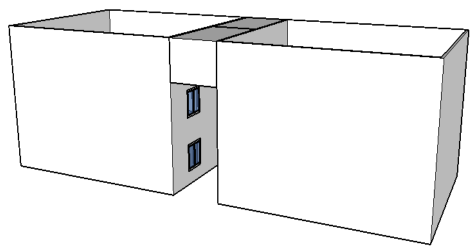


Fig. 9. Two bridged rooms may be built to connect between two houses. This treatment has the advantage of shading the setback and the rooms may be used for the family. (Source: the author)

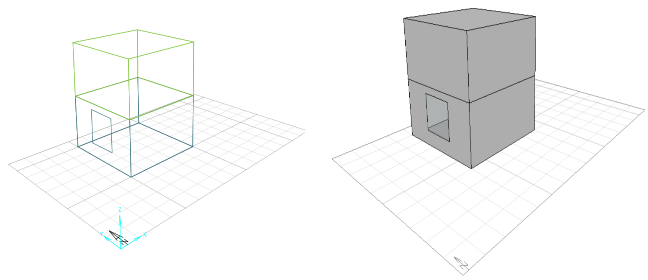


Fig. 10. Cooling loads Ecotect test model with unshaded window in the climatic region Eastern Province

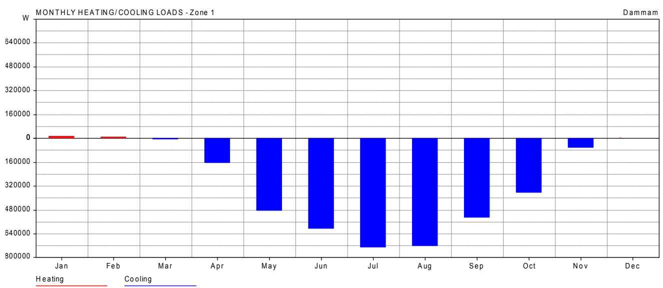


Fig. 11. Heating and cooling loads for the ground floor for the test model with unshaded window

However, in the current residential area in the Eastern Province, the bridged room would shade part of the setback which is used privately by the family, unlike the shaded public street in the traditional town which was created by the bridged room.

Proposals discussion: To test the effect of lack of cultural concerns and climatic factors in the design of a Saudi house in the climatic region of the Eastern Province, the researcher modelled a simplified, representative local house form based on the data collection in this research. The window is assumed to be closed throughout the year due to cultural concerns, and therefore its opening is restricted. The analysis shows that cooling loads during the year are very high and a total of 37,166,25 watt hours are needed to maintain the temperature between 18-26°C (Fig.11 and Fig.12).

MONTHLY HEATING/COOLING LOADS

Zone: Zone 1 (Ground Floor) Operation: Weekdays 00-24, Weekends 00-24. Thermostat Settings: 18.0 - 26.0 C Max Heating: 324 W at 06:00 on 15th February Max Cooling: 1369 W at 16:00 on 21st July

Table 1. Cooling loads for simplified model that does not respect climatic and cultural factors

HEATING	COOLING	TOTAL	
MONTH	(Wh)	(Wh)	(Wh)
------------	--------	--------	--------
Jan	12791	0	12791
Feb	9546	0	9546
Mar	990	9211	10201
Apr	0	164731	164731
May	0	488842	488842
Jun	0	607848	607848
Jul	0	731122	731122
Aug	0	722456	722456
Sep	0	535520	535520
Oct	0	365154	365154
Nov	0	65531	65531
Dec	2882	0	2882
------------	--------	--------	--------
TOTAL	26210	3690414	3716625
------------	--------	--------	--------
PER M2	1048	147617	148665
Floor Area:	25.000 m2		

MONTHLY HEATING/COOLING LOADS

Zone: Zone 1 (Ground Floor) Operation: Weekdays 00-24, Weekends 00-24. Thermostat Settings: 18.0 - 26.0 C Max Heating: 400 W at 06:00 on 15th February Max Cooling: 1819 W at 15:00 on 19th June

Table 2. Cooling loads for a simplified model that respects climatic and cultural factors

HEATING	COOLING	TOTAL	
MONTH	(Wh)	(Wh)	(Wh)
------------	--------	--------	--------
Jan	9118	0	9118
Feb	6272	0	6272
Mar	494	1761	2255
Apr	0	112597	112597
May	0	383799	383799
Jun	0	490552	490552
Jul	0	597795	597795
Aug	0	592159	592159
Sep	0	435437	435437
Oct	0	289656	289656
Nov	0	49259	49259
Dec	1852	0	1852
------------	--------	--------	--------
TOTAL	17736	2953016	2970751
------------	--------	--------	--------
PER M2	709	118121	118830
Floor Area:	25.000 m2		

The analysis also shows that the highest cooling loads are in the hot season from May until October. July and August recorded the highest cooling loads, so in these two month in particular there is a need for an active cooling system because of the high humidity levels (Table.1). However, a significant reduction in cooling loads has been achieved when implementing a culturally and climatically effective shading of openings.

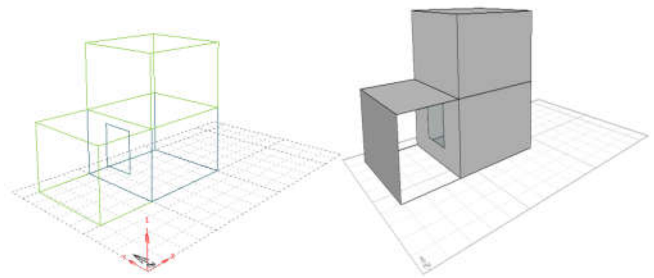


Fig. 13. Test model with climatic and cultural effective shade

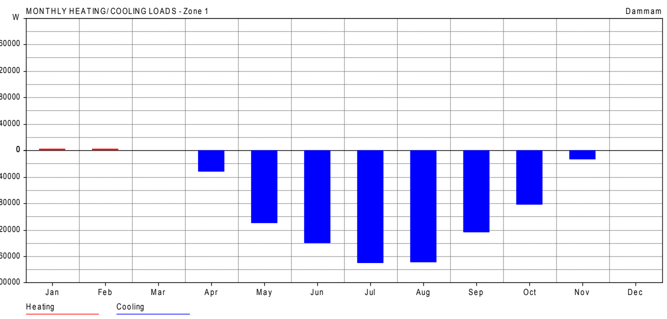


Fig. 14. Heating and cooling loads for the ground floor for the test model

The researcher has added, for the same test model, a shading element that would allow cross ventilation by opening the window and at the same time it gives complete privacy for the family inside the house (Fig.13). Thus, occupants' freedom to open and close windows has been increased significantly. The author's analysis shows that the cooling loads during a year for the modified house have decreased from 3716625 watt hours to 2970751 watt hours (Fig.14). This is a decrease of about 8million watt hours by using culturally and climatically effective shade structures (Table.2). This indicates that implementing simple shading with climatic and cultural consideration contributes significantly to increasing occupants' ability to actively adjust natural ventilation, reducing cooling loads and consequently reducing energy consumption.

Conclusion

The current housing design is extremely contradicting the traditional courtyard house. It is neither culturally nor climatically efficient. Despite its unresponsive features, the design could be improved to some extent. Through analysing the responses of the traditional courtyard house, the analysis revealed that shading was the main considered factor which was extensively used to tolerate the weather conditions in the traditional town. This paper proposed some forms to be implemented on openings to improve their function and to make them openable when needed. The paper also proved that by implementing the proposed solutions the cooling loads can be decreased dramatically.

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