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Energy efficient design strategies for contemporary vernacular buildings in Egypt

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ABSTRACT: Current practice of sustainable design encompasses a range of green strategies. Modern passive design concepts have learned to build upon climate responsive methodology that was found in and inspired from vernacular and traditional buildings. With the present energy crises in Egypt there is a current focus on the development of climate sensitive design building approaches. It will be the thrust of this paper to understand the precepts of passive and energy efficient climatic design, as well as their complementary and integrated roles in the synthesis of climatic sustainable vernacular typology in contemporary practice. An existing project, design center in Sinai, Egypt has been chosen for its specific representation of cold versus hot climate passive vernacular solutions. The paper adopted a mixed survey approach and will discuss how the project had reached the optimum energy efficiency, and how this pilot project could help spreading the notions of contemporary energy efficient vernacular buildings.

1 INTRODUCTION

Energy efficiency and comfort conditions in buildings was one of the crucial concerns in design and decision making phase for many architectural design process in the last few decades (Hirst 1986, Nieboer 2012). However, it was one of the main and prime concerns in vernacular architecture through ages (Fathy1973, 1986). Incorporating energy efficiency, renewable energy, and sustainable green design features into all building types has become a top priority in recent years for designers, policy makers and others due to the biggest challenge faced by the world which is the energy crises and global warming (Nieboer 2012 & Kreith et al 2007). Energy efficient buildings reduce both resource depletion and the undesirable environmental impacts of pollution generated by energy production (Singh et al. 2011). In another words that reduction in artificial energy (fossil fuel based energy sources) consumption directly leads to reduction in CO_2 emissions to the environment.

Significant number of research work and publications in the last 10 years are looking thoroughly in the environmental performance and energy efficiency of vernacular buildings (e.g, Rasulo 2003, Stasinopoulos 2006, De Filippi 2006 Eyu¨ce 2007 & Singh et al. 2009). Other research went deeply in investigating the thermal performance using simulation tools and onsite thermal measurements (e.g, Dabaieh 2011, Ahmadreza & Vellinga 2011 & Coles et al. 2012), and that what Fathy (1986)had started earlier in the 80 s, using simple field measurements at that time.

Politicians and practitioners in the building sector in Egypt are recently and gradually realizing the urge need for a more sustainable approach in building design and construction. It is believed that by introducing tight environmental and sustainable criteria in building practice is the only way for the country to reduce the increasing rate of pollution, and to reduce the energy consumption of the building sector. The mainstream awareness is increasing, as well as more conscious about the necessity of incorporating sustainable and environmentally friendly practices. Also recently is the notion of eco-labels, which are currently valid and applied to hotels. In addition to that, a new tailor-made label is currently being developed by the Egyptian National Research center for Building and Housing to fit Egypt's specific environment. However, the government is trying to put codes, regulations and legislations together with measures for energy efficient and climatic building design but the government's plans and efforts are still not ambitious enough to cope with the real need.

Environmentally, Egypt cannot cope with the increasing demand for energy that is the same in the majority of developing and uprising countries. According to the situation analysis and task force reports, all efforts are now targeting to contribute in mitigating this crisis through resource efficient housing system with reduction in energy usage (Handoussa 2010). Moreover, Egypt will not meet CO_2 emission reduction targets by the year 2020 plans (NREA, 2010/2011 annual report) without supporting energy efficiency gains in the building sector. Failure to encourage energy-efficiency and

low-carbon solutions for new construction will certainly avoid disadvantages of poor performing buildings for decades. To meet the increasing energy needs, particularly in a developing country like Egypt, the climate responsive buildings are the most appropriate and efficient solutions to this energy problem. That requires looking again towards the vernacular architectures that have existed in Egypt throughout ages, in order to learn how they were energy and resource efficient.

Learning from vernacular in contemporary sustainable and climatic responsive design will be the main focus of this paper. Together with the understanding of the principles of passive and energy efficient climatic design, and the integrated roles in the synthesis of a climatic sustainable vernacular typology in contemporary practice in Egypt. The case of the design center in Saint Catherine in Sinai will be discussed to tackle the above mentioned issues in the paper's different sections.

2 METHODOLOGY

This research paper applied a mixed approach, comprising several tools and methods. It started with a literature study for the history and the climate of Saint Catherine to stand on basic facts for the study. Then, it was followed by a site survey for the purpose of collecting information about locals Bedouins' habits and traditions relevant to climatic adaptation, building techniques and local materials used. Semi-structured interviews, site observations and field notes were the main tools used, together with photo documentation and video filming. Also interviews were conducted with the case study project design team, in order to investigate around the project concept, climatic solutions used, building materials, techniques and the trials tested on site for adaptive vernacular passive and energy efficient concepts.

In addition, a thermal comfort questionnaire survey among building users was conducted to measure the established comfort temperature during the operation time of the building over the year 2012–2013 especially during hot summer days and cold winter nights. Then, the methodology was summed up by an analytical study, to reflect the facts gathered from the site survey with the facts analyzed from the questionnaire.

3 CASE STUDY: SAINT CATHERINE CENTER OF BUILDING CRAFTS IN SINAI, EGYPT

Saint Catherine center of building crafts in the town of Saint Catherine was chosen as a case study for this paper research work. It is in the Sinai Peninsula in Egypt at an elevation of about 1600 meters from sea level. The region is a UNESCO World Heritage area for its natural and cultural importance (Kamil 1991). As it is a nomadic culture, the tent structure is the most common type of dwellings. However, beyond the monastery that dates back to the 6th century, several early stone structures were noticed in Saint Catherine, which means that it is one of the vernacular building traditions in the area. Along the years, and due to the changes in social activities in Saint Catherine, local inhabitants started to leave the mobile tent structures to settle in non-mobile settlements. They used mainly stone together with palm or acacia tree wood, as they were the main available local materials. From the Bedouin tent to the courtyard house, the built environment was traditionally shaped by deeply rooted responses to climate.

Considering the climatic characteristics, Saint Catherine is located in the semi arid climatic zone. It is considered a challenging extreme case in achieving thermal comfort, due to the fluctuation of temperature between day and night in both summer and winter. It also needed intelligent design to achieve indoor thermal comfort during both hot summer days and cold winter nights. The buildings should offer warm sunny spaces in winter and shaded places with cold breath in summer.

From the climatic weather analysis and the site experience in Saint Catherine, winter (from December till February) is very cold, specially at night as it might reach below zero degrees. However, winter mornings are sunny and warm most of the time. Nevertheless, it becomes suddenly cold in winter mornings, when the sun with its low angle, hides behind the mountains. Dealing with the extreme difference in winter temperature along the day, between cold indoors and warm outdoor mornings it provoked designer of this project to use solar heating in many applications for better environmental building performance.

Generally, the concept in designing Saint Catherine training centre is to apply values that are economic, ecofriendly, and culturally responsive to the social needs of South Sinai Bedouins (Ibrahim 2011). The main building materials used were stone and earth (Fig. 1). As from the project studies, stone appeared to be an appropriate building material for foundations and for bearing wall structures, as it stands against seasonal floods. The first three courses where built from stone, and the rest of the walls were built from moulded earth. Casted earth was chosen as an environmental, aesthetical and economical building solution that suits the environment of Saint Catherine. Thick walls that reached up to 50 cm for the exterior walls act as a thermal insulator for the building. The high

Figure 1. Using moulded earth and local stones showing the integration between local materials and the project site location. (Credits: Nashwa Ibrahim).

Figure 2. The layout of the project showing the choice of the site was based on climatic considerations. (Credits: Nashwa Ibrahim).

thermal mass of the walls helped keeping the building cool in summer mid days, and warm in winter cold mornings.

The design team decided for a building non-dependant on sunny western façades as the location is surrounded by mountains, because as mentioned, the sun disappears early behind the mountain (Fig. 2). So, they depend mainly on the southern façades, as they receive most of the sun rays needed for passive solar heating in winter.

In summer, it is hot during the day, but due to the fact that the air is dry, providing shaded areas is one of the effective solutions to cope with hot summer mornings. The design orients the building's main façade towards the North-South, to receive the prevailing cold breath needed for summer hot mornings, and sun rays needed for solar heating in winter. In addition, inner courtyard was one of the design solutions to cope with summer and winter climatic adaptations (Fig. 3). With cross ventilation, the court, when it is shaded in summer, acts as a container for cold air; and when it is left open in

Figure 3. The courtyard as a main element in the design offering shaded and semi shaded areas for summer and winter use. (Credits: Nashwa Ibrahim).

winter, it acts as a field for warm air. All the design decisions are derived from analyzing the adaptation of Bedouins' tents and stone vernacular buildings; and from discussing with locals their adaptive solutions and accumulated trials in dealing with their climate and environment.

One important lesson from vernacular building tradition in Saint Catherine is dealing with seasonal floods flow direction and location, as they are a major factor to determine a construction's location. The study of "Appropriate Building Patterns for Saint Catherine" shows that floods activity also affects the building foundation level, floor level, and door way direction. Therefore, locating and positioning a building in a construction site are very important decisions in such a climatic and topographic context (Ibrahim 2011). From site walking interviews with locals, it is mentioned that for the last ten years Saint Catherine had been suffering from rainfalls, which had a direct affect and influence on life, and even on building aspects. So now, the knowledge on how to avoid floods is unfortunately gradually disappearing and that might has extreme environmental effects in the future on the built environment. Ibrahim also mentioned in the study that "Bedouins have the knowledge of flood paths, but they started to build in flood areas since rain has been decreasing, as a direct result of global warming", and she advised that documentation of possible flood-threatened areas needs to be carried out by geographical information systems (Ibrahim 2011:12).

The window design was inspired from vernacular practice in Bedouins' dwellings, which is adaptive to comfort needs. Openings are required to keep out cold winter winds, and to allow warm sun rays in, during the winter mornings. Also windows should provide shade and allow for the cool breeze to enter during summer time. Generally, openings were designed with a recess, which provides

Figure 4. Different opening sizes inspired from ventilation and natural indirect light solutions in Saint Catherine vernacular buildings. (Credits: Nashwa Ibrahim).

Figure 5. A window frame acting as a trombe wall using goat hair., where goat hair provides shading in summer and would act as a heat absorber in winter. (Credits: Ibrahim, 2011).

protection against weather, as well as adequate shading (Fig. 4). One of the designers' innovations using locals' knowledge is a trombe window. A wooden frame holding goat hair with two hinged vertical panes instead of the louvered window sash, which swings horizontally, where goat hair sheet provides adequate shading in summer, and would act as a heat absorber in winter. Goat hair also closes its pores when rain falls on it, thereby holding off water (Fig. 5). The ceiling, which is the most exposed part of the building to direct sun rays in summer time, was constructed from several layers of palm reeds, wood logs and a layer of earth mortar. This helped reducing the thermal heat transfer from the ceiling to the internal building envelope.

4 POST OCCUPANCY QUESTIONNAIRE SURVEY

The building users were asked about their satisfaction with the temperature inside the building

Figure 6. Roof structure developed based on roofing vernacular techniques in Saint Catherine. (Credits: Nashwa Ibrahim).

both in summer and winter time. They were also asked about the air quality and natural light (visual comfort). Together with this survey, an investigation about energy consumption was conducted by comparing monthly energy bills. The aim was to investigate how efficient the building is, when compared to another conventional building with the same size. The outcome of the post occupancy thermal comfort questionnaire with the building users along the year 2012–2013showed that 70% were satisfied with the thermal comfort for winter and 85% for summer seasons, 90% with the natural light (visual comfort) and 95% were satisfied with the indoor air quality. The percentage of discomfort was mainly for the winter season, from December till March, where the temperature drops down to below zero degrees at night time. It is due to the fact that it takes some time in early winter mornings to heat up the building using the trombe walls. Building users tend to use electric heaters during winter evening for heating purpose. This post occupancy survey needs to be supported by monitoring indoor temperature, using data loggers during peak time in summer and winter, in order to have an accurate evaluation for the indoor thermal comfort. As for energy consumption, the building proved to be more efficient in summer time, when compared to conventional ones with the same size; while in winter time, during the months from December to February, the energy consumption is almost the same as in conventional ones, due to the use of electric heaters inside the building.

5 DISCUSSION

Vernacular buildings are examples of intelligent buildings that are well adapted to the local climate (Sundarraja et al. 2009). The gathered knowledge of vernacular know-how, and the continuous

sequence of trail and errors, made vernacular buildings able to achieve high energy saving with self-regulated amendments (Slessor 2006). The main philosophy was to reach energy efficient, comfortable and natural spaces by passive ways with low cost and using the resources available. Together with occupants' response, locals have control on building elements and building energy systems to provide users' comfort by a minimum amount of energy demand (Dabaieh 2011).

From site investigations it appeared that in the last 15 years there is high investment in tourism industry in Saint Catherine and there has been more reliance on energy-consuming technology in the form of heating, cooling, and ventilation to achieve thermal comfort in tourist buildings. There is a deficiency in providing electricity in Saint Catherine due to bad infra structures, and that caused a lot of problems, considering the dependency on active heating and cooling systems.

The tendency to respond to climatic conditions using passive, low-energy strategies to provide for human comfort; strategies that are integral to the form, orientation and materiality of the buildings were not a major concern in the design strategies of newly built structure, either residential or for tourism purpose. That stresses on the importance of retaining back the local vernacular architecture know-how in achieving thermal comfort, which was totally neglected in the majority of buildings there. Taking the case of Saint Catherine city there are some attempts and trials in different eco-lodges and safari rest houses, but still not enough for future sustainable climatic responsive design.

This paper shows it is possible to design and build vernacular climate responsive architecture, creating thermo-efficient and sustainable contemporary buildings. Current applications are still in a very small scale building, and more research is still needed. However, such applications are a good guidance for small and medium size residential buildings. The vernacular tradition of buildings could help forming ecologically responsive architecture that is both ecologically sustainable and satisfying human needs in our hot climatic zones. As De Filippi discussed in her research, vernacular built heritage can be seen as the core of sustainability, due to the fact being constructed and built with local materials with the least amount of resources waste (De Filippi, 2006). Also, as Heal and his colleague researcher mentioned, many times one can find the solution to optimize the use of resources and to achieve the human thermal comfort by critically evaluating the vernacular architecture of that place (Heal et al, 2006).

Energy efficiency in buildings offers an obvious opportunity for both developed and developing countries, to cooperate in achieving common but differentiated actions to accomplish significant CO_2 emissions reductions. More legislation is needed towards tariff levels to encourage using the vernacular concepts that had been forgotten, and to test and verify using its contemporary applications, together with the encouragement of local innovation and sense of belonging to local know-how, and appreciation of own's culture and tradition; instead of a globalized image that blurred all the spectacular significance of each society and culture.

Modern trials constructed with today's advanced building technologies have no matching consciousness to local environment, regardless the fact of the possibilities offered by the simulation tools in energy area. It should not be forgotten that sustainable architecture should start with understanding of vernacular timeless trial and error. Therefore, the aim of this study was to ring the alarm that it is necessary to consider the deep meanings behind vernacular forms and using local materials, to integrate scientific methods with vernacular low-tech sustainable ways of building.

As a summary, vernacular architecture can contribute to the future of the built environment as a model for sustainable designs. We need to make use of the most beneficial inherent and timeless knowledge of vernacular architecture.

6 RECOMMENDATIONS

Quantitative survey in measuring thermal comfort along different seasons especially in the peak time during July/August in summer and January/February in winter is needed for accurate evaluation of the building thermal performance. That is to measure how far it was responsive to different climatic extreme conditions. Also CO_2 calculation is recommended, together with comparing energy consumption and energy bills, along 5 years of building operation. This research paper focused on one climatic zone and it should be carried out for different climatic regions, like hot humid regions, Mediterranean regions, etc. Guidelines could be formulated from studying the vernacular solutions for each specific climatic zone. That will be a clue for designing contemporary buildings using climate responsive design derived from vernacular concepts.

7 CONCLUSION

In this paper energy efficient and low energy passive strategies in building design have been analyzed for Saint Catherine center in Sinai, Egypt, through the analysis of the vernacular experiences

and contemporary modern trials. In the study, the climate responsive strategies inspired from vernacular building know-how are introduced. The paper shows how vernacular architecture provided useful insights for designing contemporary buildings, by taking vernacular design principles and clues into account. This research proved that it is still needed to learn from vernacular buildings, which were built before nowadays' construction and the energy supply technology, in the same climate zone; as they are more energy efficient and are well responsive to the local environmental conditions, when compared to contemporary buildings.

Finally, the importance of vernacular passive climate sensitive and sustainable design, as well as its awareness of regional environmental and material concerns, demands a fresh look at the issue of the vernacular, as it pertains to the practice of contemporary climatic responsive and energy efficient buildings. We should reconsider our green building policies, as it not a luxury; it is a signal of national possible future survival.

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