Architectural Design with Environmental Solutions as a Scope for Sustainability: Achieving Energy Efficiency in Buildings Passively

Mostafa Atwa

Abstract

Responding to the local climate and site conditions has always been a vital strategy, especially when it is accompanied by minimizing energy consumptions. Over the last decades, the dependence on mechanical equipment has rapidly increased in Egyptian residential buildings. Locally, simple passive strategies, as shading, orientation, thermal mass, daylighting and natural ventilation are rarely considered in the architectural design process. However, residential buildings are the major electric energy consumers in the building sector. Therefore, this research investigates the potential of the re-introduction of passive cooling strategies as a method of diminishing energy consumption in buildings. Moreover, the study focuses on Cairo as a location for the study and residential buildings as a typology, for its high-energy consumption rate. The local Psychometric chart was studied in advance to identify the critical problems of the studied climate and to suggest the suitable passive cooling strategies to be investigated, and a reference building was selected within defined criteria for the experimental phase. The experimental phase was conducted by the means of Design builder, which uses Energy Plus as a simulation engine, and several selected passive cooling strategies were examined on the reference building. The study revealed several findings that can be illustrated in a 54.8% of cooling energy reduction in the reference building. Besides, the study shows the potential of the examined design alternatives through the possible energy savings of each alternative. Finally, the study raises a question of why these strategies are abandoned and what can be achieved by the wide applications of passive cooling strategies on residential buildings in Egypt.

Keywords: passive design, sustainability, energy efficiency

1. Introduction

Today, environmental and energy problems pose as the number one global problem. Significantly, climate change due to the increasing temperatures caused great concern all over the world. Therefore, man has no choice but to diminish energy consumption rates. As population and energy concerns increase, the demand for low energy practices is urgently needed. In order to recommend low energy architectural practices, passive design has been proposed as a solution (Omer, 2008). Passive design is an approach to building design that utilizes architectural design to minimize energy consumption and to improve thermal comfort. In other words, passive architectural design is to consider all the surrounding environment of the building in the architectural design process, which results that the building responds to all the needs and potentials of its local climate and can dramatically reduce primary energy consumption. The optimum target of passive architectural design is to eliminate requirements for active mechanical systems and to sustain thermal comfort for occupants (Cheung, Fuller, & Luther, 2005) (Mikler, Albert Bicol, Breisnes, & Labrie, 2008).

During the last 60 years in Egypt, architects and designers neglected traditional knowledge of local suitable techniques due to the westernization. In other words, passive design strategies such as shading, orientation, thermal

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1 mostafa.atwa@hotmail.com
mass, natural lighting and ventilation are no longer considered in the architectural design process (Abdel-Razek, 1998) (El Araby, 2002).

In 2014, residential buildings in Egypt was the major consumer of energy recording 52% of the total produced electrical energy of the country as shown in Figure 1 (EEHC, 2015). Furthermore, electricity consumption for residential buildings is expected to reach 35% growth yearly in the future, based on the 10% yearly increase from 1998 to 2008. Moreover, energy consumption of several residential buildings was examined and it revealed that cooling energy is the major required load in the building, achieving 67% of the total energy consumption of the unit.

Additionally, Egypt is characterized by the massive utilization of prototypical design in governmental housing projects, which doesn’t take into consideration the climatic factors, coupled with poor quality in the construction industry (Mourtada, 2009) (Georgy & Soliman, 2007).

1.1 Research Problem

The problem addressed by the research can be based on the following: first, high energy consumption rates are recorded for cooling due to the massive expansions in using mechanical air conditions. Besides, climate change caused high summer temperatures, which reflected on the cooling energy. Second, the governmental residential projects are characterized by the massive utilization of prototypes in most of the cases, which doesn’t consider the local climate, orientation or any specific consideration for each location. Consequently, this prototyping results in a massive increase in the energy consumption levels. Therefore, passive cooling strategies that are durable and low technology can dramatically be an approach for controlling the energy consumption and saving cooling energy.

1.2 Research Aim

The research investigates the potential of re-introducing the passive cooling strategies as a method of diminishing energy consumption in buildings. Therefore, the main goal of the research is to investigate the effect of suitable passive cooling strategies on residential buildings cooling energy in the climate of Cairo, which is the capital of Egypt and the highest expanding local urban community. For achieving the main goal of the research, different types of passive design were explored, and the effect of different passive strategies on cooling energy consumption rates of a local selected case study was assessed. Finally, feasibility of the passive strategies will be investigated in the selected local climate, and the evaluation will be through the required energy demand for cooling the building.
2. Literature Review

Passive cooling is considered as the highest efficient energy conservation method and it has the lowest economic impact in comparison with mechanical systems. Most studies in hot climates have revealed that most of the energy efficient spaces are those which use passive techniques for cooling. Thus, passive cooling systems and strategies have achieved significant interest by designers and architects recently (Santamouris, 2007).

Moreover, the passive cooling of buildings is broadly categorized under three sections as shown in Figure 2 (Geetha & Velraj, 2012). The first stage focuses on designing a building that reduces and minimizes the energy needs by various factors, such as neighborhood planning, building layout and orientation. Generally, a building should be designed to be compatible to the climate of its region and its microclimate. Reducing the internal gains of the building is vital for improving the effect of passive cooling techniques. Site design and planning aspects are considered a key factor for reducing internal gains, as designing a site is influenced by many factors, for example; economic considerations, zoning regulation and adjacent developments. Controlling the solar radiation is the initial step towards heat gain protection (Yannas, 1990). Second, the following stage is concerned about modifying and modulating the gained heat, through the building envelope with all its components as windows, walls, roofs and shading elements. Managing a building thermally was mentioned previously to be an effective stage to reach energy reductions. The building envelope is the tool in achieving the heat modulation strategy, as it absorbs heat during the day and regulates the magnitude of indoor temperature, reduces peak cooling load and transfers a part of the absorbed heat to the night hours. Generally, it is responsible for minimizing heat loss in winter and heat gain in summer. At last, using the modulation and solar protection strategy in many cases may not achieve the full targeted thermal efficiency level. Therefore, the third stage concentrates on getting rid of the heat that enters the space using the upper atmosphere and the ambient sky by the natural processes of heat transfer. Dissipation of the excess heat depends on two main conditions: the availability of an appropriate environmental heat sink, and the establishment of an appropriate thermal coupling between the building and the sink combined with a sufficient temperature difference for this transfer of heat.

In other comparative climates as the hot humid climates, the application of passive measures and strategies for example, glazing, shading, insulation, and natural ventilation was highly effective in reducing the cooling load of buildings achieving 43% reductions (Omer, 2008). Therefore, applying of suitable passive strategies to Cairo’s climate is expected to be highly effective and result a reduction in the energy consumption of the tested buildings.

3. Cairo’s Case

3.1 Cairo’s Climate

Köppen’s climate classification sorted Egypt as a hot arid climate region. The allocated symbol for the climate of Egypt is BWh; where (B) refers to hot dry, while (W) specify that precipitation < ½ water consumption and letter (h)
indicates that the average annual temperature exceeds 18°C as shown in Figure 3. Hot arid climates are specified by exceptionally hot dry summer, dry winters, and continuous sunshine for the whole year, and maximum temperatures of 45°C. (Henderson-Sellers & Robinson, 1986) Moreover, according to the Egyptian Typical Meteorological Year Authority (ETMY) report that the annual average temperature in Cairo is 22.4 °C with a maximum average temperature of 35.4 °C and minimum average temperature of 20 °C in the peak summer month (July and August) and a maximum average temperature of 18 °C and minimum average (Atwa, 2016). Finally, the psychrometric chart was generated using Climate Consultant 6.0 in Figure 4. showing the comfort zone on the chart and suggested passive design strategies to be implemented in the Cairo’s summer climate from May to September, moreover, the strategies predicted effectivity are displayed by percentage (CIAO, 2015).

![Figure 3. Koppen Climate Classification Map](image)

Figure 3. Koppen Climate Classification Map
Source (Köppen, 2006)

![Figure 4. Psychrometric chart of Cairo’s Climate](image)

Figure 4. Psychrometric chart of Cairo’s Climate
Source (Climate Consultant 6.0, 2015)

### 3.2 Local Case Study

The reference project for the experimental phase of this research was selected to be in the 5th settlement of New Cairo city as shown in Figure 5. The criteria for selecting this reference project is as follow:

- Repetitive prototype so developed design solutions will have wide impact.
- Family housing typology causes a chance of minimum stakeholders of the building.
- Under construction, therefore new building regulations can be applied.
- Previous examples are available of the same prototype so it can be analyzed to reach the human practices inside the building.

![Figure 5. Perspective of the studied reference building](image)

Figure 5. Perspective of the studied reference building
Source (New urban communities authority, 2015)
As shown in Figure 7, the masterplan of the selected reference project consisting three zones of land plots ranging around 300 m², the plots have different orientations in all the orientation axes. The four main axes had the higher percentages than the secondary axes, while land plots facing East axis orientation achieved the highest percentage across all the axes by 24.6%, and the lowest percentage was achieved by the South-west orientation by 4%. These results showed that the major effective land plot category of the whole project is the East orientation, which in consequence could have a massive impact positively or negatively on the overall energy consumption. Furthermore, the building gets attached to one of its adjacent neighbors forming one bigger building. Also, the selected prototype had two different architectural plan proposals to give the highest flexibility and to figure out the effectivity of the passive means on each unit. Therefore, the same floor area was used in two different architectural plans, the first as one unit as shown in the architectural plan, while the second as two twin units on the two opposite short sides of the land plot as shown in Figure 6. Additionally, the typical building consists of four floors in the form of a ground floor and three typical floors. Similarly, the three floors are typical in the architectural organization, including the last floor. Not only the difference between the two designs is the surface area of the unit, but also the one unit design consists an additional bedroom.

4. Methodology

4.1 Parametric Simulation Structure

The research objectives shape and determine the suitable methodology that is necessary to achieve the experimental stage of the research. Moreover, the methodology of the study will be constructed in several stages. In other words, the study was conducted on a residential building in Cairo in a stepped parametric analysis. The study investigated the effect of several suitable passive cooling strategies selected referring to the climatic analysis of the location. Each
strategy was investigated in a sequential process as shown in Figure 8. The evaluation of the whole process is through the achieved reduction in the cooling load. Additionally, a comparison between the base case and the final improved proposal in the terms of required cooling load will be conducted to show the effectiveness of the applied strategies.

**Figure 8. Methodology of the Research**  
*Source (Author, 2015)*

Design-Build was selected as a simulation software for conducting the energy simulation. It comprises a core 3-D modeler and 9 modules which work together to provide in-depth analysis of energy use, consumption and commitment for any building was selected for the analysis. Design-Build illustrated that the simulation program had the most comprehensive user-interface for the most widely used energy simulation engine Energy-Plus and daylight simulation engine of Radiance and DaySIM (Maile, Fischer, & Bazjanac, 2007). With the capabilities of Design-Build, all the passive techniques could be investigated in the research process through Design-Build, and parameters of each strategy will be proposed in its section.

4.2 Reference Case Performance

Practically, a complete urban cell was modelled in Design-Build to be like the reality and to consider the shading effect of adjacent buildings in the form of adiabatic components to facilitate modeling data and save simulation time as in Figure 9. Referring to the statistics about the land plots in the masterplan of the project, the reference case was
modeled to face East orientation. In addition, the materials illustrated in Table 1. were used as input data for the model in Design-BUILDER.

![Figure 9. The modeled urban cell of the project](source: Design Builder, 2015)

<table>
<thead>
<tr>
<th>Walls</th>
<th>Roof Slab</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.00m2 Brick wall at 350 degrees</td>
<td>25.00m2 Glass window frames</td>
</tr>
<tr>
<td>0.30m2 Glass window frames</td>
<td>6mm Single Clear Glass</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Typical Floor Slab</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.00m2 Wood floor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ground Floor Slab</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.00m2 Concrete floor</td>
</tr>
</tbody>
</table>

Moreover, the simulation was conducted in the base case to determine the default cooling load and indoor air temperature to be used for the evaluation of the different studied strategies in the further stages of the research as shown in Chart 1 & Chart 2 respectively. Since that the last floor gets the highest solar radiation, it was used as a reference space for the air temperature examination. On one hand, it was found that Bedroom 1 in Unit B (BB1) has the highest indoor air temperature. On the other hand, the initial annual cooling load of the building is around 51,000 kWh.
4.3 Applied Strategies

In this part of the research all the determined strategies in the previous methodology of the research will be examined and its effect by itself will be determined and explained. Moreover, the heat control stage was neglected from the application stage, as the masterplan was already planned and executed.
Roof Insulation

The roof of the building is the most exposed building element to the direct solar gain. In contrast, the current roof construction is not insulated. The upgrading in the U-value of roofs over the years worked on improving the thermal performance of roofs to increase the overall thermal performance of buildings. Therefore, the roof of the building was modified to contain 5 cm insulation within it, and the insulation used was EPS (Expanded Polystyrene Standard). Particularly, the material was used from the material directory of Design-Builder, and the new roof slab was as illustrated in Figure 10.

Wall Types

The wall area of the building is the greatest among all the building enveloped components, therefore the wall type could have a great impact on the energy consumption of the building by the transfer of heat through it. In this part of the study, four wall types were investigated as alternatives for the exterior wall of the building as shown in Table 2. Finally, alternatives were compared with the base case wall which was a single red brick wall.

<table>
<thead>
<tr>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
</tr>
</thead>
<tbody>
<tr>
<td>25cm Brick</td>
<td>25cm + 5 cm Air Gap</td>
<td>25cm + 5cm Int. Insulation</td>
<td>25cm + 5cm Ext. Insulation</td>
</tr>
<tr>
<td>1.77 W/m²K</td>
<td>1.24 W/m²K</td>
<td>0.55 W/m²K</td>
<td>0.55 W/m²K</td>
</tr>
</tbody>
</table>

Glazing Type

Glazing is responsible for nearly 30 % of energy loads of a building, and it has a large impact on the thermal comfort because of its effect on the indoor air temperature (Lechner, 2014). Therefore, single glazing in the windows was substituted with three other alternatives of glazing to investigate the effect of glazing on the required cooling load as in Table 3.
Table 3. The proposed glazing alternatives

<table>
<thead>
<tr>
<th>Glass 1</th>
<th>Glass 2</th>
<th>Glass 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Tinted (Blue) 6mm</td>
<td>Double Clear 6mm 13 mm air gap</td>
<td>Double Tinted (Blue) 6mm 13 mm air gap</td>
</tr>
<tr>
<td>5.77 W/m²K</td>
<td>2.66 W/m²K</td>
<td>2.66 W/m²K</td>
</tr>
</tbody>
</table>

**Window Shading**

Many studies positively supported the impact and importance of shading elements on the heat gains in hot arid climates. After testing the shading configurations to achieve the optimum balance between adequate daylight inside most of the spaces and thermal performance, the simulation results and successful configurations were inputted to Design-Builder to study the effect of shading elements on the whole building through calculating the required cooling load. Figure 11. shows the application of shading as standard components in Design-Builder.

![Figure 11. Applying shading configurations to Design-Builder](image)

**Roof Shading**

After the positive effect that was found by window shading in overcoming solar radiation, a shading surface will be utilized to overcome solar radiation affecting the building’s roof. Not only improving the thermal performance, but also shading the roof gives the opportunity of utilizing the roof as a used outdoor space. However, insulation was

![Figure 12. Roof shading in Design Builder model](image)
utilized in the new alternative roof in the study, but on one hand, shading the roof could give more improvement. On the other hand, the simulation could conclude the higher effective strategy on the roof, the shading technique or the roof insulation. Thus, shading was introduced to the Design-Builder model through a standard component as shown in Figure 12.

**Night Ventilation**

Night ventilation was reported to be an efficient cooling strategy in hot arid climates (AREE, 2011). It works by utilizing temperature differences in improving ventilation. In other words, cool night air is presented to the building replacing the indoor hot air. In consequence, a reduction in the mean radiant temperature of the space can be achieved, while by day, hot air is prevented from entering the building by changing window operation. (Geros, Santamouris, Karatasou, Tsangrassoulis, & Papanikolaou, 2005)

Therefore, night ventilation was investigated during summer in the study, and window operation schedule was created in design builder. Moreover, windows glass panels are closed from 8:00 to 20:00 in front the air flow, while keeping daylight entering. During the winter, heat resulting from occupants, light and electrical equipment’s was used to improve internal spaces temperatures, besides closing the windows to sustain this heat. Moreover, sufficient ventilation rates were considered during the whole day.

**Cross Ventilation**

Wind-driven cross ventilation occurs when opposite openings exist to allow air flow through them, as difference in wind pressure between the openings forces air to move (Emmerich, Dols, & Axley, 2001). Therefore, cross ventilation was investigated in the study. Cross ventilation will occur through creating air flow between windows and doors. Hence, doors were set to open 5% of the day hours coupled with 20% of the door area, while the introduced alternative will have the door open 100% of the day hours coupled with 100% of the door area as shown in Figure 13. Additionally, the window is operated at night as the previous applied strategy, thus this strategy will play an effective role in distributing the cool night air in the whole unit.

![Figure 13. Door operation cases](image)
**Wind Catcher**

Wind catchers is one of the oldest passive dissipation techniques used in residential buildings of high dense cities to drive fresh cool air inside the building directing it to living spaces, and louvers could be added to protect the interior of the building and volume control dampers are used to control the flow (Li & Mak, 2007).

Moreover, a cross-section of 1.2m x 0.8m red brick walls was used for the wind catcher, and the window opening in the internal spaces was 0.8m x 0.8m. Besides, locations of wind catcher in the floor plan was selected to enable directing air into two adjacent living spaces by the same wind catcher to minimize number of constructions, and the long side of the wind catcher was designed to be open toward the prevailing wind direction.

Furthermore, wind catchers were modeled in Design Builder as shown in Figure 14, and zones were created as cavity zones, the exterior opening was created as a window operating using the same night schedule applied previously as all the windows. In addition, the wind catcher strategy was applied on all the living spaces, even the spaces that have windows directed to the north, as they enhance the chance of assembling air, as they are higher than surrounding buildings.

5. Simulation Results

5.1 Effectivity of the Applied Strategies

In this part of the research the outcome of each strategy will be explained through its effect in reducing the cooling load of the building and analyzing its effect on the different units or levels of the building.

In the heat modulation stage, EPS roof insulation with thickness 5 cm was applied to the building, which improved the U-value of the roof, and its effect was limited mainly to the last floor, resulting a reduction of 1200kWh, and it could be considered as a part of the overall reduction strategy. More improvement can be obtained by increasing insulation layer thickness, but in this case cost analysis should be considered. Also, different wall types were proposed and applied to the building, applying different thicknesses of walls, insulation and air gaps resulted in an effective reduction of the energy consumption of the building by 15.6%. The highest reduction occurred in the case of a 25cm red brick coupled with 5 cm EPS insulation installed on the exterior side of the wall. More improvement can be obtained by increasing insulation layer thickness, but similarly cost analysis should be considered. Additionally, three different glazing types were proposed and tested to reach the best performance. The glazing type appeared to be effective in blocking direct sunrays recording 14.2% in the case of double tinted glazing. More reduction could be obtained by using triple glazing. Furthermore, window shading was introduced by a simple horizontal louver system in a vertical layout to the building to overcome the solar radiation, besides providing adequate daylighting was considered. Therefore, a parametric study was carried out to reveal the optimum configurations, which reaches the balance between the daylight requirements and thermal performance. Consequently, the shading strategy was effective in energy reduction achieving 7.31%. Roof shading was introduced to decrease the solar radiation falling on the roof.
of the building, and the effect of the technique was limited to the last floor. Thus, it barely decreased the total energy consumption by 1.37%.

While in the heat dissipation stage, night ventilation was utilized by assigning a window schedule that closes windows during midday peak external temperatures and operates during the night to cool the indoor environment. Internal temperatures were reduced and consequently the energy consumption decreased by 6.34%. During winter, the internal heat gains were sustained by closing windows, however appropriate ventilation rates were supplied. Cross ventilation was introduced after the new schedule of the windows, and cross ventilation was implemented by keeping doors open during opening windows to create an inner flow of air. Particularly, cross ventilation improved the energy efficiency by 3.44%. Improving ventilation in order to improve cooling was a target. Therefore, another ventilation strategy was introduced to improve the previous strategies by enhancing the flow of the cool air coming from the North direction through wind catchers. Moreover, the strategy improved the total energy performance by 4.073%.

Additionally, all the possible reductions of different applied passive strategies and remarks for improving performance were illustrated in Table 4. At the end, we can conclude that residential development in climatic conditions of Cairo is a great opportunity to adopt energy efficient practices to form energy efficient and sustainable communities.

Table 4. The effectivity of the applied strategies and analysis remarks

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Specification</th>
<th>Effect and Reduction Ratio</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Insulation</td>
<td>Inserting an EPS insulation layer of thickness 5 cm</td>
<td>2.5%</td>
<td>More reduction can be achieved by increasing the roof insulation thickness</td>
</tr>
<tr>
<td>Wall Types</td>
<td>Using a 25-cm wall of red bricks</td>
<td>4.84%</td>
<td>More reduction can be achieved by increasing wall thickness</td>
</tr>
<tr>
<td></td>
<td>Inserting an air gap of 5cm between two layers of redbrick of thickness 12.5cm</td>
<td>8.72%</td>
<td>More reduction can be achieved by increasing air gap</td>
</tr>
<tr>
<td></td>
<td>Inserting an EPS insulation layer of thickness 5cm between two layers of redbrick of thickness 12.5cm</td>
<td>13.59%</td>
<td>More reduction can be achieved by increasing insulation layer thickness</td>
</tr>
</tbody>
</table>
Inserting an air gap of thickness 5cm between two layers of redbrick of thickness 12.5cm

| Glazing Types | Glazing Type: Single Tinted (Blue) 6mm | More reduction can be achieved by using triple glazing
| Shading | Glazing Types: Double Clear 6mm 13 mm air gap | More reduction can be achieved by using triple glazing
| Shading | Glazing Types: Double Tinted (Blue) 6mm 13 mm air gap | More reduction can be achieved by using triple glazing

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| Shading | Glazing Types: Double Tinted (Blue) 6mm 13 mm air gap | More reduction can be achieved by using triple glazing

| Night Ventilation | Limiting window operation to certain times of the day | More reduction can be achieved by applying an automated air temperature responsive system and to control the door operation with the window operation.
| Cross Ventilation | Improving flow of air through the inner spaces by keeping doors always open | More reduction can be achieved by examining different cross-sections and positions of the wind catcher
| Wind Catchers | Improving the air flow by installing wind catchers oriented towards North direction | More reduction can be achieved by examining different cross-sections and positions of the wind catcher

5.2 Total Reduction

In general, the results of the simulation carried out in this research revealed the great potential of utilizing energy efficient practices in Cairo. In addition, these energy efficient practices were proposed in this study through passive strategies and techniques, which massively improved the energy efficiency of the studied residential building. Moreover, the total energy consumption for cooling of the building decreased by 54.8% as shown in Chart 3. To conclude, the achieved energy savings provide an example of the possible energy reductions that could be accomplished in the future built environments. Chart 4, presents a comparison of the initial buildings internal temperatures and the final modified version proposed for summer months of Bedroom 1 of B unit (BB1), which shows that highest recorded internal temperatures was improved and deviated towards thermal comfort ranges.

Total Reduction

In general, the results of the simulation carried out in this research revealed the great potential of utilizing energy efficient practices in Cairo. In addition, these energy efficient practices were proposed in this study through passive strategies and techniques, which massively improved the energy efficiency of the studied residential building. Moreover, the total energy consumption for cooling of the building decreased by 54.8% as shown in Chart 3. To conclude, the achieved energy savings provide an example of the possible energy reductions that could be accomplished in the future built environments. Chart 4, presents a comparison of the initial buildings internal temperatures and the final modified version proposed for summer months of Bedroom 1 of B unit (BB1), which shows that highest recorded internal temperatures was improved and deviated towards thermal comfort ranges.
6. Conclusions

Referring to the objective of the research, the aim was to define passive cooling strategies concerning about their characteristics, classifications and typologies. Consequently, the literature review of this study included a list of basic principles in passive cooling building design and different techniques. Furthermore, different applications of passive strategies were studied in diverse climatic conditions through multiple international experiences. Moreover, investigating the efficiency and potential of applying passive cooling strategies in the local climate of Cairo shaped the research methodology. Therefore, out of numerous passive design strategies and techniques that were discussed in the theoretical framework, selection of the suitable and appropriate strategies and techniques with the climatic conditions of Cairo to be applied. The study was carried out through different stages revealing several findings as the following: first, the research revealed that passive cooling strategies could have high potential in reducing the energy...
consumption levels of residential buildings in Cairo, reaching a 54.8% cooling load reduction of the building. Second, effects of different strategies were revealed and discussed to support users and stakeholders with a guideline for applying these strategies. Finally, the recommendations and a discussion on why passive strategies are abandoned nowadays will be discoursed in the following section in brief.

Passive design features showed to be highly effective in achieving energy efficiency in buildings. Thus, it would be expected that these strategies are widely used and practiced in Cairo’s urban development, but in the real time it is rarely utilized in Egypt. Therefore, a question could be proposed “why isn’t passive design applied widely?” Based on the different experience, few reasons will be proposed and different involved roles will be pointed out to identify the barriers.

First reason that could have affected the application of passive strategies or energy efficient practices is the non-obligation. In other words, the lack of enforcing regulations formed by the responsible authorities. Therefore, the authorities have an important role to adapt the construction sector by developing regulations and codes for energy efficient developments.

Another reason is formed by the building owner, as they could play a key role in overcoming the energy crisis, but in reality, owners are interested in maximum profits through low construction standards and costs coupled with maximum utilization of the land plot. Therefore, awareness should be widely used to develop their knowledge about the importance of adopting these strategies and the economic benefits for them. As a conclusion, further studies could be conducted and the research introduces these recommendations:

- Examining more passive strategies or more parameters of the studied strategies.
- The integration between the passive design and energy production using Photo-Voltaic systems, which could can reach the minimum energy consumption rates.
- The scope of a framework for implementing the energy efficiency strategies that were discussed in this research.
- Cost-benefit analysis, as the results will provide developers and users with a clear view of opportunities and risks to invest in passive buildings.
- Feasibility study of the execution of passive strategies.
- Passive strategies implementation for outdoor thermal comfort, which could be taken in consideration for planning.
- A national strategy should be considered involving the different roles to participate together to achieve the target of energy efficient buildings in Egypt.

At last, it is important to closely examine and implement passive design strategies, as they could be modified to be adapted to today’s buildings. Passive strategies were developed by many generations of architects and builders; therefore, we should not abandon using these strategies.

REFERENCES


