Sustainable Design for the Residences in Gaza City

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Abstract
It has been understood that the environmental impact of housing design, construction and operation has lower priority in research studies as compared to the conventional interests in cost, size, form, location and aesthetics. Gaza’s climatic data indicates that both cold and warm percentages are in the extreme values such as finding a flexible design tool that can satisfy human comfort is an important requirement in a predominantly sustainable architecture concept. Using this new concept to improve the thermal environment and ventilation of buildings through identifying, developing, and testing innovative concepts that can have potential for achieving human satisfaction in homes. Herein, basic principles of Successive Integration Method have been utilized on some materials and varying passive elements to achieve an adequate module’s elements. An integrated design with floor cooling and heating, natural ventilation and some additional passive techniques found that indoor temperature could be properly maintained.

Keywords: thermal comfort; sustainability; natural ventilation; Successive Integration Method (SIM)

Introduction
Gaza has several severe climatic problems through the year, the monthly mean high air temperature is (31.2) °C in a typical summer, and the monthly mean low air temperature is (6) °C in the winter. Table (3) in the appendix shows hourly outdoor conditions of the hottest and coldest day of the year 2002. It proves that difficulties of the changeable climate, which affects people inside houses. Nevertheless, the existing environmental concerns for thermal comfort focus on the summer rather than the winter due to the lack of mean annual precipitation (410) mm. On the other hand, simple constructional materials, poor techniques, absence of insulation for walls and roofs and lack of shading devices are a common phenomenon. Accordingly, people are negatively unsatisfied with their tackling, hence feeling uncomfortably cold and warm during the winter and the summer (1). It is necessary to consider both climates in the process of designing the thermal characteristics of residences. Herein, achieving healthy housing designs within the most modest means in a sound environment is urgently needed.

To solve such problems, a proposal has been adopted for passive mobile strategies that consider the relation of the human, the building and the climate. Four parameters: shading devices, ventilation, insulation for walls and roofs and floor’s heating and cooling were conducted in the study in order to obtain a unique solution for indoor climate. The effect of the design’s elements on rooms’ temperature has been studied to improve indoor spaces. This assists the future design to prioritize using tools and materials in terms of sustainability.

2. Objectives
The paper aims to achieve:
(a) Required and convenient design’s elements for Gaza’s climate.
(b) Constructional details within environmentally modern concepts. These elements should consider the comfort zone of humans, which is defined as “the range of climatic conditions within which the majority of persons would not feel thermally discomfort either heat or cold” (2). Herein, the comfort zone is arranged at 21-29 °C in both winter and summer.

3. Method
This paper is particularly developing and adopting some calculative equations, in addition to Successive Integration Method (SIM) to evaluate the thermal environment of the structure. The Successive Integration Method (SIM) is defined as “a tool used to predict transient heat-transfer in a building by assuming a quasi-steady state between the building members and the room air temperature” (3). Herein, the accuracy of simulations has been positively confirmed by SIM.

4. Proposal’s Descriptions
The preceding preview clarified that both cooling and
heating during the year are required. A proposal (Fig.1 and 2) of gross area (134m²) is prepared for developing the thermal environment of future houses. An integrated design with natural ventilation, southern solar panels (36 m²), and a floor radiant cooling and heating system, in which pipes of cold and hot water are embedded inside the concrete floor slabs have been implemented. It is consists of two floors, a penthouse and a 6 m a chimney.

4.1 Performance of Passive design

Passive design concepts are set for enhancing an indoor thermal environment. The processes of enhancement are discussed and described hereafter.

4.1.1 Natural Ventilation

The main route of natural ventilation has been conducted with the “chimney” concept. The main route provides several zones of spaces with fresh air. Airflow in each route can be induced by utilizing the tendency for warm air to rise and be displaced by the cooler air. In summer nighttimes (Fig.2), the floor’s chimney is closed and then the route of ventilation goes down from chimney’s openings to the indoor spaces. This occurs due to the out door air being denser than the indoor air, which in turn encourages driving the force of the flowing air from more dense to less. It cools internal surfaces of construction and can be cooled for the next day.

In winter daytimes (Fig.2), the floor’s chimney is opened and then the route of ventilation mainly provides indoor spaces from lower openings of basement. The exausted air will be replaced by fresh air.

4.1.2 Solar Panels

Active solar tools for heating and cooling in the proposal used built collecting panels, pipe, an automatic pump and a sensor for controlling the movement of shutters. This system collects, stores, and distributes the collected solar energy inside spaces. It depends on the solar energy and radiation. Therefore, a passive concept is created throughout this active system to compose an approach of sustainability. In the proposal, panels are supported by water as a means of heat transfer and directed south to collect as much heat as possible. These panels tilt with an 45° angle “Approximately, solar collectors for space heating systems are usually tilted at an angle equal to the appropriate angle of latitude plus 10 degrees”[4].

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**Fig.1. Model’s Plans**
In the active solar heating system, heat is reticulated from the solar collectors to the floor pipes and back to the collectors. The heat transfers from pipes to the indoor spaces by conduction and convection. The heat will be stored in the construction materials, which have a heavy thermal capacity.

4.2 Terms in Simulations

In the simulation, different heat resources were studied for estimating the heat balance of rooms’ air temperature. The resources that were considered as follows:

4.2.1 Internal resources

The internal thermal resources from lighting, the human body, and equipment with a dimensional unit (Wh/ day) are considered. The heat are emitted from the human body is approximated by 25 (W/m²) and the average area of the human body’s is approximated by 2 m². Totally emitted energy of the human body is calculated to 50 W, while five people were considered in the study. The life pattern of those people was different from time to time. Occupying times from (4pm till 7am) was considered. The heat from lighting, other internal resources and equipments are added to the human body’s energy to accumulate 12050 W.h/day.

4.2.2 Construction Materials

External walls with/without insulation, windows, roofs, and floors with pipes transfer heat energy from side to side by the processes of conduction and convection. The process of calculations has considered the characteristics all materials’ layers, sub-layers and hourly outdoor temperature. The thermal conductivity, diffusivity of each layer and the net of long and short wave radiation are done. Respectively with applying SIM, temperatures of solids’ surfaces and layers were estimated. When a surface temperature is finally known, then most of the heat will be exchanged between the air of the room and the solid surface such as a wall by convection heat-transfer (3).

4.2.3 Passive technique

a) Solar panels in case.6 (Table 2) are conducted to the study. Some terms were used in the calculations for measuring panels’ area. The calculations were dependant on the material’s characteristics such as walls, roof and window conductance, required ventilation for occupants, difference of temperatures between average outdoor temperature and human comfort zone, internal heat resources and long wave radiations from the roof to the sky. Evaluations for the net heat have estimated the required area in the summer and the winter and that was approximated to 36 m². On the other hand, to evaluate the heating and cooling effect of the solar panels’ system on the rooms’ temperature, common equations and definitions were used for this purpose, such as Reynolds, Prandtl and Nesselt Numbers (5). Pipe diameter of the solar panel and the floor were done for 1.20 cm.

b) Natural ventilation has been conducted to the model. Fluctuation of temperatures, difference of pressure, and air leakage has been studied. Fresh air flow is simulated according to the difference of temperatures between chimney’s indoor and outdoor tempertaures. Orifices of the chimney are contributed ventilating

Fig.2. Conceptual Sections of “Winter’s Case in the Daytime” and “Summer’s Case in the Nighttime”
spaces through different levels of openings (Fig. 2). The location of the natural pressure level at which indoor and outdoor pressures are equal is controlled by the size and the location of leakage openings. Many cases were studied to estimate the height of the chimney. It was noticed that the preferred height is chosen to 6 m.

5. Analysis and Results of Simulations

The list of conducted conditions for simulation is shown in (Table 1 and 2). The processes of executing the simulations have taken many procedures. Each case tests one or more parameters’ effect on rooms’ air temperature. Gradually, these analytical processes will have achieved the most valuable and affected parameters for summer and winter by the end of this chapter. The hottest and coldest day of the year were used for the numerical simulations table (3).

Case1

Case1 (Table 1 and 2) is commonly built in Gaza; hence houses are simply constructed by concrete structure with one external cement-block sized 0.40*0.20*0.20 m and cement plaster in both external and internal sides with thickness 0.03 m (1). In this case, the openings are being actualized for the current medium openings. Passive ventilation of spaces is poor and unfamiliar. Non-insulated walls and roofs and the absence of shading devices are commonly found.

In summer

Case1 has been conducted and it is noticed that, indoor air temperature has an increased average of about +5.30 °C, to reach an average of 35.55 °C, while the average outdoor air temperature was 30.25 °C (Fig. 3). Differences of average air temperature between the basement and outdoor indicates +1.45 °C to reach an average of 31.70 °C; while about a +8.00 °C difference between the penthouse and the outdoors that reaches the average temperature of 38.25 °C. Indoor air temperature negatively affects people inside these spaces; hence its air temperature is being laid outside the thermal comfort of human zones of +6.55 °C (i.e. 35.55-29.00 °C). The quantity of heat inside spaces is very high due to the absence of passive designs. It is noticed that the temperature has accumulated gradually from the lower degree of the basement floor to the higher degree at upper floors, which in turn compel one to examine some design tools to evaluate the temperature.

In winter

Minimum outdoor air temperature was about 4.01 °C on the coldest day of the year and the average air temperature was about 6.90 °C. A difference of air temperature between higher floors and outdoors shows an increase of +1.50 °C that reaches the average
temperature of 8.40 °C. The indoor air temperature has increased the average of about +0.50 °C to reach an average of 7.40 °C, while the basement has an average difference of -0.50 °C with average of 6.40 °C (Fig.3). The difference of average air temperature between the basement and higher spaces such as the living spaces and the penthouse are gradually increased from 0.90 to 1.90 °C (i.e. higher floors have higher temperatures than lower floors, due to the differences of solar gains and thermal performances). The calculated temperatures are out the thermal comfort regions by -13.60 °C (i.e.7.40-21.00 °C). This practice ensures that the existing buildings deal summer rather than winter.

Case 2

To achieve healthy buildings, ventilation is needed through the summer and the winter. This case has conducted the ventilation and compared to the non-ventilated case1.

In summer

This case has been compared to case1 and it is noticed that the accumulated heat inside the living spaces is decreasing during morning times and nighttimes to have a difference of up to -2.70 °C that reaches the average air temperature of 32.85 °C. Improvements have occurred consequently for the basement and the penthouse with 1.65 °C in the basement to reach an average of 30.05 °C and -3.30 °C in the penthouse that reaches the average of 34.95 °C (Fig.4). The achieved temperatures are out of the comfort zone, while the basement has closer value to the comfort zone than other spaces for its direct relation with the ventilation inlet. Therefore, the ventilation could positively affect and lessen rooms’ air temperature.

In winter

Being compared to the original case1, it has been noticed that ventilation reduced the average temperature inside all spaces of about -0.40 °C (Fig.4). Ventilation is mainly a summer tool, while in winter it works negatively. In winter airtight buildings are desirable. Sizing orifices that are significant should be strongly evaluated for achieving more distinctive thermal comfort. The needed temperature for achieving thermal comfort zone is enlarged of about -14 °C (i.e. 7-21). Case3b1

Shading devices with wall type-A and with the absence of ventilation are being practiced in this case to emphasize the effect of shading devices on the solar gains of windows.

In summer

This practice has been compared to the original case1. A significant difference of air temperature of up -2.60 °C shows an improvement in the penthouse that reaches the average to 35.65 °C. An improvement of indoor spaces is approximated to -0.60 °C to reach an average of temperature of 34.95 °C (Fig.5). Much gain of solar radiation reflects much loss in case of non-insulated houses (case3b1). On the other hand, this case is compared with case2 and it is noticed that ventilation has stronger effect than shading devices by +2.10 °C; hence the transmitted solar radiation is noticeably reduced in hot and sunny days. In winter, there is no difference between this case and case1 due to the altitude angle, which causes a capability for penetrating the spaces. Shading devices is a summer tool that should be considered in the design.

Case3b2

For mitigating the thermal environment of indoor spaces, it has combined the ventilation with walls type- A of case2 and the shading devices of case3b2, which reduce the solar radiation in the building during the summer season.
cases individually. The operation process of shading devices is expressed to prevent the solar radiation from penetrating while ventilation improves the thermal environment.

**In winter**

Case 3b1 combines cases 2 and 3b1. A discussion has been deeply done. Repeatedly mentioned that the shading devices have no effect during winter, while ventilation should be controlled during the winter. This case is being compared to case 1 and it is noticed that the base case shows an improvement unlike this case due to the ventilation performances. In this case the temperature of living spaces has been reduced by -0.4 °C and -0.65 °C in the penthouse (Fig. 6).

**Case 4**

For improving the thermal environment of indoor spaces in the summer and the winter, insulated walls and roofs, shading devices and small openings are being conducted. This case is carried out with the absence of ventilation.

**In summer**

Comparing this practice to the original case 1, it is noticed that a gradient temperature is improved of up to -1.80 °C in living spaces to reach an average of air temperature of 33.75 °C; while in the penthouse an improvement is occurred of -4.5 °C that reaches an average of 33.80 °C due to the efficiency of shading devices and the insulation, which is reducing the heat transfer that improves indoor spaces (Fig. 7). On the other hand, case 4 is compared with case 3b1 to show the effect of the insulated walls with small openings. It has been noticed that case 4 has improved the thermal environment of indoor spaces rather than the case 3b1 of 1.20 °C.

**In winter**

There is an improvement of about +0.60 °C in living spaces to reach an average of 8.00 °C and +1.00 °C in the upper spaces to have an average of 9.40 °C (Fig. 7). Comparisons between this case and case 3b1 have been done and it has shown an improvement of the average of indoor spaces during the winter of +0.65 °C. It indicates that utilizing insulated roofs and walls with small windows have a highest priority (i.e. insulation provided the ability for maintaining the indoor thermal environment and reducing heat transfer).

**Case 5**

Pervious case 4 is being conducted with the ventilation but without high technology evaluations such as solar panels. Some comparisons have been done mainly with case 1. Other cases have been compared to this case to show the effect of each parameter on rooms’ air temperature individually.

**In summer**

Comparing this case with case 1, an improvement in temperature of about -3.90 °C has been obviously shown in living spaces that reach the average of air temperature of 31.65 °C; while improvements have been observed in the basement and the penthouse of -1.92 °C and -6 °C respectively.

That reaches the average of air temperature in both spaces of 29.8 °C and 32.16 °C (Fig. 8). Generally, the average temperature of indoor spaces is considered to be about 31.20 °C. This leads to a closed value of human comfort zone, which is identified between 21-29 °C.
during the winter and the summer. To achieve the comfort zone of humans, -2.65 °C is needed for living spaces. This case should be developed to perform thermal comfort inside living spaces. On the other hand, case 5 has improved indoor spaces rather than case 3b2 and case 4; hence the ventilation and insulation are included in the process. Temperature is decreased due to the smaller openings, dimensions with shading devices, thermal massive walls, and natural ventilation, which in turn reduce indoor temperature. Accordingly, the natural tools could mitigate the climatic severe problems of Gaza.

In winter
The ventilation negatively affected indoor spaces, while opposite occurs where insulation is used. Thus, a small improvement of +0.5 °C has been shown in the living spaces (Fig.8). The average air temperature of 7.90 °C in the living spaces shows that the tackling is not enough for the winter’s problems while it works positively in the summer. Keeping the internal temperature stable as much as possible is a must. This case is compared with case 4; it has been shown that case 4 works better than case 5 in the winter due to the existence of the ventilation. This case needs development and improvement to achieve the thermal satisfaction.

Case 6
The previous case 5 integrated solar panels 36.00 m², floor pipes on the first and the second floor, an automatic pump and shutters. The performance of solar panels has been explained in section 4 of this study. This case is compared to the original case 1 and other conducted cases. The results are shown hereafter.

In summer
Water flows into floors through embedded pipes. This system is supported by an automatic pump, which works during the summer’s nighttime. Moreover, a sensor is used for controlling movement of shutters, which are shutting the panels during the daytime and opening them during the nighttime. Comparing this case to the original one, it has been noticed that an improvement of up to -6.30 °C in living spaces to reach maximum average of 29.25 °C and -8.00 °C in the upper spaces to reach maximum average of 30.25 °C (Fig.9A). Water temperature of the panels was cooler than indoor spaces of up to -3.20 °C, thus it enhances the natural cooling system inside the spaces. This case is being compared to case 5 and it has been observed that the difference of temperatures has been positively noticed in living space and the penthouse respectively of +2.40 °C and +2.00 °C. The effect of using solar panels is obviously proved that indoor spaces have achieved the required zone of thermal comfort. Therefore, it is reasonable to exploit and utilize the solar panels to reduce the gradient temperature.

In winter
Shutters shut the panels during the nighttime and open them during the daytime with running water in the pipes during the daytime. Comparing this case to the original case 1, it is noticed that a considerable improvement of indoor spaces of +16.40 °C that reaches the average of air temperature of 24.80 °C (Fig.9B). The penthouse has an improvement of +11.15 °C that reaches of an average of 19.55 °C. This case is compared to the previous case 5 and it has been found that the difference of temperatures of both cases is +16.90 °C. This practice successfully tackled the heating system of living spaces during the cold weather and highly achieved the required zone of thermal comfort.

6. Summary and Recommendations
For achieving the thermal comfort zone of the original case, it was noticed that there is a required temperature of 6.55 °C cooling, 13.60 °C heating in living spaces while in case 5, consisting of shading devices, insulation, ventilation, and small openings with double glass panes, required 2.65 °C cooling, 13.10 °C heating. But in the case 6, the proposed model, it is noticed that the comfort zone is almost achieved hence only -0.25 °C is only needed in summer, while in winter the heating load is
covered. The results are satisfied; hence the required temperatures for achieving thermal comfort of human are obtained.

Assembling the most effective and natural parameters, which developed the thermal environment of indoor spaces is desired to lessen the environmental problems in term of sustainability.

Form the previous cases the effect of the most effective parameters on room’s air temperature are gradually assembled such as follows:

6.1 In Summer
1. The solar panels with small openings affected living spaces positively of -2.40 °C.
2. The ventilation affected living spaces by -2.70 °C.
3. The insulation within type wall-B affected living spaces of -1.20 °C.
4. The shading devices affected living spaces of -0.60 °C.

6.2 In winter
1. The solar panel affected interior spaces positively of +17.40 °C.
2. The insulation influenced indoor spaces positively by +0.60 °C with controlling the ventilation.

Therefore, it is recommended to adopt them through the future processes of design and planning. Design’s characteristics of case6 are affordable, applicable and reliable in term of sustainability.

Notes
Some abbreviations were used above. The interpretations hereafter:
1. (Ent - Entrance, LR - Living room, DR - Dining room, K - Kitchen, Ba - Bath, Sp - Space, BR - Bedroom, R - Room, CR - Chimney space)
2. (Z-Zone) and Zones are arranges in the simulations as follows: (Z1- Floor of stairwell, Z2- Ba + Ent + LR + Sp, Z3- DR + K, Z4- Ba + Two BR, Z5- Two BR, Z6 Penthouse, Z7- Chimney's room, Z8- Water pipes in ground floor, Z9 - Water pipes in first floor, Z10- Water pipes in the cantilever of first floor, Z11- Water pipes in solar panels, Z12- Second floor’ stair, Z13- Third floor( stair).

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Appendix

Table 3. The Hottest and Coldest Day of 2002 (Gaza City)

| Time (hr) | 12/04/2002 | 28/01/2002 | 28/01/2002 |
|----------|--------------|-------------|-------------|
|          | °C R.H       | °C R.H      | °C R.H      |
| 1        | 25 74.90 92  | 61.2        | 61.2        |
| 2        | 24.6 75.87 5 | 61.2        | 61.2        |
| 3        | 24 77.04 4.2 | 61.4        | 61.4        |
| 4        | 25 77.5  4   | 69.65       | 69.65       |
| 5        | 26.2 74.30 5 | 59.30       | 59.30       |
| 6        | 27.6 68.32 6.2| 56.60      | 56.60      |
| 7        | 29.6 66.52 5.2| 53         | 53         |
| 8        | 30.4 65.51 4.4| 50.82      | 50.82      |
| 9        | 35 67.12 5.8 | 55.25       | 55.25      |
| 10       | 35.6 67.61 6.4| 56.25      | 56.25      |
| 11       | 36.6 68  7.8 | 56.03      | 56.03      |
| 12       | 36.7 67  8.4 | 55.65      | 55.65      |
| 13       | 36.8 67.50 8.6| 56.40      | 56.40      |
| 14       | 36.6 68.36 8.8| 55.40      | 55.40      |
| 15       | 34.2 68.12 8.8| 56.02      | 56.02      |
| 16       | 31.3 70  7.4 | 54.50       | 54.50      |
| 17       | 29 71.22 7.4 | 54.02       | 54.02      |
| 18       | 28.2 70.85 7.8| 54.05      | 54.05      |
| 19       | 29.4 71  7.5 | 55.85       | 55.85      |
| 20       | 30.6 70.66 7.4| 55.60      | 55.60      |
| 21       | 31 70.82 7.4 | 56.87       | 56.87      |
| 22       | 30.2 71.50 8.2| 57.52      | 57.52      |
| 23       | 30 71.81 7.8 | 58.52       | 58.52      |
| 24       | 27.4 72.97 7 | 58.64       | 58.64      |