Improving Thermal Comfort Through Natural Ventilation and Passive Solar Systems in Residential Buildings in Iraq: Review Paper

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Abstract The building enterprise in Iraq performs the greatest instance of energy, especially in residential section. Indeed, most of the residential constructions rely on traditional construction systems. In the past, the traditional system used to supply thermal comfort for residents during summer and winter seasons. However, due to the fact of the growing impact of global warming and technological advancement, this constructional system is no longer viable. Therefore, realizing energy efficiency, specifically in Iraq, is very vital due to non-stop electricity crisis since the 1990s. Hence, this review paper is an attempt to show several strategies to achieve thermal comfort in residential buildings in Iraq through natural ventilation and passive solar systems for both cooling and heating periods, which at the end can help to achieve some kind of sustainability in residential buildings in Iraq, specifically, hot climates in general.

Keywords Natural ventilation · Energy efficiency · Sustainability · Hot dry climates · Thermal comfort

1 Introduction

Iraq is characterized by very high temperatures in the summer and moderate in winter. The highest values in June, July, and August are between 43 and 50 °C and in January between 1 and 8 °C [1]. Winds and water cause natural hazards such as dust storms. There are two types of winds and dust storms in Iraq. From June to September, the country is affected by dry air masses from the Mediterranean [2]. This leads people to use air-conditioners excessively during the summer to bring suitable thermal comfort environment inside their desired space. Besides, there is a shortage in electricity in Iraq [3], which causes the power to get shutdowns as a result of power consumptions especially by air-conditioners. Hence, roof is one of the most important elements of a

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M. Awang and M. R. Meor M Fared (eds.), *ICACE 2019*,
Lecture Notes in Civil Engineering 59, https://doi.org/10.1007/978-981-15-1193-6_24

building. Roof, walls, and ventilation are the most important parameters in a building that contribute to heating load in old and non-insulated buildings [4]. Therefore, if we control thermal gaining through ceilings, we can provide thermally comfortable indoor climate, reduce air-conditioner usage and power consumption, reduce cooling demands, and improve current houses' energy efficiency to achieve sustainable status. Thus, this study is a review on improving thermal comfort through ventilation and passive solar systems inside residential buildings by considering Iraq as a part of hot and dry climatic zone.

2 Thermal Comfort Problems in Hot and Dry Climates

The fundamental purpose of a building is to shield the residents from the outside circumstances, such as heat in summer, cold in winter as well as wind and rain. Hence, an applicable indoor climate should be designed for buildings. An international issue on source of power and environmental problems is prompted to reflect on consideration of many factors for the design of buildings. According to a large number of research works, in order to indicate the climate and its suitability for the building design and building materials, designers and/or architects have to be aware of the characteristics of the local weather in their working environment. Furthermore, based on the related climatic elements, they will be capable of categorizing the construction problems and observe or endorse their solutions to keep away from them.

In order to design a building with thermal comfort and suitable indoor climate in hot climates, primarily, the common construction problems have to be recognized. The following elements are commonly referenced in many studies:

- High temperature
- High solar radiation
- Moisture or high RH level
- Excessive heat gain in summer
- Heat loss during winter.

Therefore, to acquire the stated goal, architects as construction designers, have to take a look at some of the factors in the design stage, namely construction layout, orientation, and envelope details (shape, insulation, solar control) to manage overall thermal performance and sustainability of buildings [5–13].

3 Construction Issues in Overheated Periods

In summer, in regions with hot climates, construction must be designed in such a way to decrease the amount of heat gain. To reflect on consideration on this issue, distinctive aspects of the construction should be analysed by considering two important factors: solar control and thermal insulation. For instance, for the purpose of controlling the solar radiation, considering a suitable construction layout, orientation, and shape will be really useful and will make it possible to take advantage of strategies such as shading, envelope reflective texture, and transparent envelope. In the meantime, making use of thermal insulation will grant a kind of barrier to isolate the indoors from outdoors, and consequently, it can manipulate the consumption of energy and cost. As mentioned above, solar management is one of the major techniques in construction design in hot and dry climates. In order to have a successful manipulation on solar radiation, the following parameters have to be taken into account precisely [8–10]:

- Building layout, form, and orientation
- Building envelope
- Opaque envelope (including walls and roofs)
- Transparent envelope (including walls and roofs).

4 Passive Solar Systems

Different techniques of designing and constructing a passive system can be classified into two groups with two essential strategies: managed heat gain strategy or passive heat gain, and passive cooling method. Each of these techniques can be divided into four simple systems: direct gain, thermal storage wall, attached sunspace, and convective loop (Fig. 1).

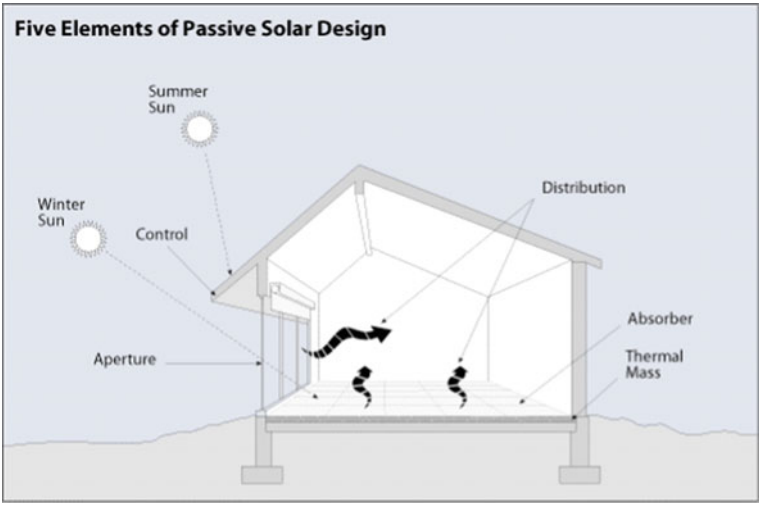

Fig. 1 Five elements of passive solar system (*Source* URL evereco.org/sustainable_building.html)

Each one of these fundamental passive systems consists of five collectively dependent fundamental components: collector, absorber, storage, distributor, and manipulator [8]. Here, each strategy and its associated subsystems will be described.

4.1 Passive Heating Systems

As noted above, we have four distinct passive methods. In this part, each method will be reviewed to evaluate its functionality in heating seasons briefly.

In direct gain systems, in cold season, sunlight radiates into construction through the collector, which is pointed towards south and typically made of glass. This solar radiation will be transformed into heat via elements, which have absorbed it. The heat is then either used to warm the region or stored to be used later. Normally, it is difficult to provide direct solar radiation over the whole surface area. So reflecting sunlight from light-coloured surfaces to the dark surfaces will be an acceptable solution [8].

4.1.1 Convective Loop Systems

In this system, sun rays will be transferred via the collector of the convective loop of the thermo-siphon air panel (TAP) and strike the absorber surface. The absorber has a metallic surface with back colour, which converts solar radiation to heat. It should be located in two subsystems, which are vertical and U-tube panels. In vertical panel, in order to avoid warm room air from being drawn back into the panel, simple backdraft dampers are generally supplied at the vents. But, in U-tube panels, shut proximity of the inlet and outlet vents will furnish a benefit for this system in comparison to vertical panels (Fig. 2) [8].

4.1.2 Attached Sunspace System

In this system, sun rays pass through the collector, which is directed towards the south and then, they are absorbed by elements and is transformed to heat. This procedure is the same for all its subsystems such as open wall, direct gain, air exchange, and thermal storage wall subsystems. For instance, in open wall and direct gain subsystem because of no opening, there is a direct and free transfer of warm air between two spaces. In order to avoid immoderate loss of heat, it is recommended that high-performance glazing be used, or in direct achieve systems, the use of transportable insulation which is positioned at the shared wall will limit the extra heat losses from building (Fig. 2) [8].

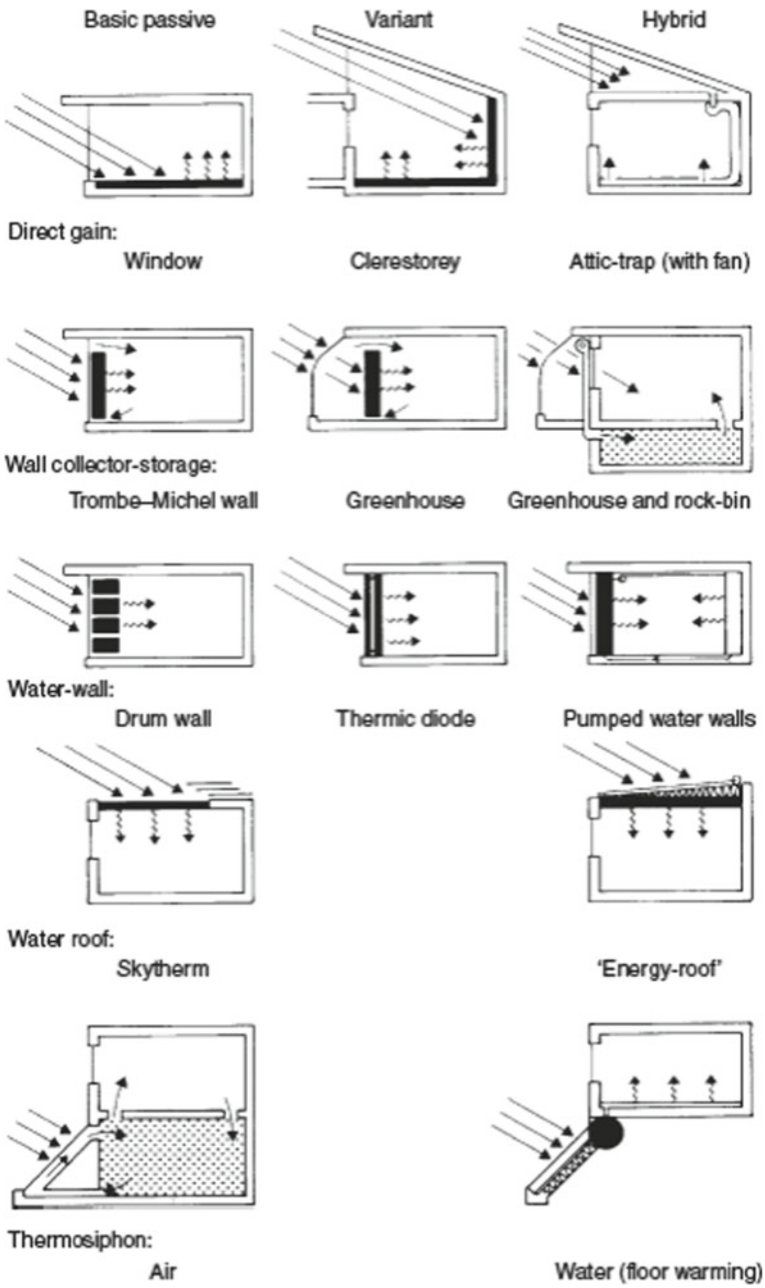

Fig. 2 Main types of passive solar heating systems [19]

4.1.3 Thermal Storage Wall System

In summer, solar radiation comes in via the collector, hits the storage wall, and makes it warm. In the state of unvented thermal storage wall, the generated heat is saved and slowly transferred to the interior. Because of the tendency of hot air to go up and cold air to come down, in the vented wall system, a natural ventilation system will supply hot air to the building. Although using vents will provide light and some direct heat gain to the building during the day, however, they will also decrease the efficient zone of the storage wall (Fig. 2) [8].

4.2 Passive Cooling (Ventilation) Systems

As noted at the start of this chapter, the fundamental feature of the construction is the supply of barrier from outdoor temperature circumstances to evade thermal comfort problems. One of the factors which commonly create thermal comfort problems is relative humidity stage and moisture content of the construction envelope. Since in hot and humid climate normally there is an extra quantity of steam in the air, therefore, in cold season, this quantity of steam will be absorbed through construction envelope and at some point in hot season, it will be launched again to the air from construction envelope. Thus, extra quantity of moisture content in construction envelope could be an enough resource for distinct kinds of issues in the case of thermal comfort or structural defects. These sorts of defects could be listed as condensation, structural warmth loss, and moisture motion through affecting sturdiness of construction materials, which will be mentioned later [14–19].

On the other hand, immoderate quantity of steam in the air will dramatically impact the thermal comfort stage in buildings. Since the pressure of the moisture in the air relies solely on the humidity or moisture content, therefore, the steam pressure of the extra humid air inside a hot building will be greater than the steam pressure of even saturated outdoor cool air. Increasing the level of humidity could extend sweating and make life difficult. Therefore, ventilation turns into an essential function to avoid immoderate humidity. In this case, it should be provided to allow moisture in the warm internal air diffuse to the exterior through the influence of the difference in vapour pressure. There are various approaches to supply air ventilation. Using of passive or energetic systems should grant them. In summer, via stratifying some controls to passive techniques, an advantage of natural ventilation and passive cooling systems could be delivered to the building. Those controls can be described as follows.

4.2.1 Attached Sunspace System

In hot periods, this system can simply be overheated. Thus, the collector should be properly shaded to benefit from transportable insulation. In addition, sun space should be vented properly. It is extremely suggested to set low vents in the shades on the windward side of the system, and top vents on the leeward side. In addition, the storage mass in this system can also assist to cool construction if precisely designed and controlled (Fig. 2) [8].

4.2.2 Convective Loop Systems

Since convective loop systems are only intended for warming, they will be inactive throughout the hot season (Fig. 2) [8].

4.2.3 Thermal Storage Wall System

In summer, collector has to be properly shaded and resized to prevent immoderate heat gain. In case of wall vents, vents are positioned on the exterior side of the collector element in shape of opaque panels. Moreover, transportable insulation should be used to shield the collector from outer side and preserve the cool temperature of the wall as much as possible (Fig. 2) [8].

4.2.4 Direct Gain System

Through the overheated periods, collectors should be properly shaded to keep away from excessive warmth gain. Shading elements, such as overhangs, should be sized precisely to increase general overall system performance (Fig. 2) [8].

5 Constructing Issues in Under-Heated Periods

Passive solar systems are based on the precise design of the organization of the building's areas and suitable choice of building materials in order to acquire heating and cooling advantages from the natural free power resources to minimize electrical energy wastes via air conditioning systems [8].

In areas with hot climates, the use of passive solar systems will add the gain of solar heat to the building and decrease the power consumption. Because of their significance in under-heated periods, they have a dominant function in order to provide natural ventilation in overheated periods.

Fig. 3 The ventilation and openings positions in a plan [18]

Table 1 Wind velocity upon openings position [18]

Opening height as a fraction of wall height	1/3		
Opening width as a fraction of wall width	1/3	2/3	3/3
Single opening	12–14%	13–17%	16–23%
Two openings in same wall	–	22%	23%
Two openings in adjacent walls	37–45%	37–45%	40–51%
Two openings in opposite walls	35–42%	37–51%	47–65%
"Range = wind 45° perpendicular to opening"			

6 Improving Ventilation

Ventilation is optimized by providing cross-ventilation through many spaces in the house as a practical solution. In regular wind conditions, the aspect of effective to negative pressure is encouraged. Of course, the indoors design of the residence needs to allow the air to flow through and indoors doors in the ventilation route need to stay opened [20].

Ventilation effectiveness relies on wind velocity, the angularity at which the wind strikes the window, and the place and dimension of the window (Fig. 3). A room with a single opening will have solely 12–23% of the wind velocity. This improves up to 51% if openings are positioned on adjoining partitions and about 65% of the outdoor air speed can be reached with openings on contrary walls (Table 1) [20].

7 Conclusions and Recommendations in Planning, Design, and Construction Materials for Buildings in Hot Dry Climatic Zones

7.1 Conclusions

In hot and dry climatic zones, it is very important to use the available green energies such as wind and solar radiation to achieve thermal comfort for residents. Therefore, systems such as passive solar systems can provide a suitable solution for Iraq climate which is well known by the very extremist weather during summer and winter seasons. In addition, windows dimensions and positions can affect the wind velocity and the amount of humidity inside the room or the zone, which can lead to improve climate, temperature, oxygen, CO_2, and steam amount inside a room and provide better ventilation and thermal comfort for residents.

7.2 Recommendations

7.2.1 Architectural Design Recommendations

1. Using the idea of a building with an internal courtyard as a temperature regulator. Use of water and greenery in private and public yards.
2. Exploitation of flat roof surfaces as open areas (roof garden).
3. Reduce solar radiation, increase shadows, and increase humidity.
4. Use of "*shanshul/mashrabiya*" as a cooling system for buildings and also increasing the amount of shadows.
5. Use the idea of the indirect entrance to avoid climatic factors from dusty winds.
6. Avoid directing the buildings to the direction of the wind and directing the openings towards the north-west and south-west.

7.2.2 Urban Planning Recommendations

1. Use a built-in general layout that reduces the lengths of lanes and solar glare.
2. Use the style of agglomerated buildings and provide interior courtyards.
3. Use of narrow, zigzag pedestrian streets which receive the least amount of solar radiation.
4. Taking into consideration the natural terrain of the site and using plants and special trees which bear the climate conditions of hot and dry regions.
5. Pay attention to urban formations by setting heights and scales in hot and dry deserted areas.

7.2.3 Building Materials Recommendations

1. It is preferable to use materials with high thermal capacity.
2. Using prominent bricks to double the shadows on the facades.
3. Using heat insulation materials on roof tiles and between wall materials.
4. It is preferable to use a double roof to allow continuity of airflow through the building block.

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