

Design Climatic Treatments and Environmental Needs in Hot Areas

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Abstract

Since the beginning of time, the man had made his effort to build an adequate limited environment to conduct various activities. The man prepared a space that protects him from the changing climate factors around him. There are limits to climate comfort in terms of temperature, humidity, and ventilation. Past those thresholds, there is physical weakness and lack of production.

This study of the existing buildings and their surrounding environment conveys the impact of conventional architecture on the interior environment. To conclude the roles and standards that may control the thermal and climatic comfort of the residential areas. To present, a residential compound model design. Clarifying the preferred applied orientation, architectural treatments, and building mass, and gap proportions around the building in sight of (selecting materials, construction methods, and the exterior envelope of the building). Use local natural materials to achieve thermal balance, air movement, and climate comfort inside the buildings and city.

Keywords

Climate comfort, Environmental need, Solar radiation, Architectural treatments, Residential areas.

1. Introduction

The climatic changes on the earth's surface have resulted from the Industrial Revolution. Modern technologies started by specifying a complete system for building and controlling internal climate for buildings, to make up for design flaws that conflict with achieving thermal comfort for man. From here events on the earth head confirm the global warming phenomenon, which is confined between the surface and the upper atmosphere levels through the action of gases emitted from the earth, which led to an increase in temperature which could reach three times the current increase within the next 100 years (Energy and Architecture Manual, 1998).

What we need now is a global evaluation of this issue to solve it. Also, we must head towards providing thermal comfort for citizens. Thermal comfort can be accomplished using environmental solutions and using the open system rather than the closed system.

Egypt and the Arab world fall between Tropic of Cancer and Tropic of Capricorn; which is called the hot climate region, where temperature rises more than any other area in the world. This climate affects the nature of life in this region. Communities can either adapt to it or find a solution. There are several solutions to consider, especially in the field of architecture and planning.

1.1 Objectives

- Analyzing case studies of existing buildings in hot regions and deriving ideas and guiding principles accordingly.

- Measuring the effect of traditional architectural treatments on the buildings case studies' internal climate to develop a set of urban and architectural foundations and standards. The proposed result is to control thermal and climatic comfort in buildings and residential areas.
- Developing urban and architectural criteria for monitoring thermal comfort can be utilized to achieve the proposed model for a residential complex that meets the requirements and achieves thermal comfort for the individual within his residence and town.

2. Literature Review

In addition to other elements such as social, cultural, and economic aspects, the town's environment and its buildings shape the building forms most of its shape (Fathy, 1986). McMullan (2002) acknowledges that "the built environment is created in the natural environment by buildings and structures that humans construct."

While buildings and construction provide multiple benefits to society, they also have significant impacts on the environment. Enertia Building Systems (EBS) (2006) has highlighted contemporary buildings' influence as the world's second-largest industry after agriculture. Also, the emissions caused by the heating and cooling of buildings causes prominent environmental harm. It is now higher than that of vehicles (Al Mansouri, A.2009). The Building Study and Establishment (BRE) stated that construction's environmental impacts cover a broad range of problems, including climate change, mineral extraction, ozone depletion, and waste generation, according to Gomes (2003).

For example, several sources have discussed the value of climate design research; Roaf et al. explained that a transition towards lower energy and/or lower carbon society is a crucial component of sustainable development. (Roaf S.,2007)

The urban built environment has been the most energy-consuming area of society, contributing between 50% and 70% of CO₂ emissions directly to the heating and cooling of buildings and the urban population's mobility needs.

"Our generation is responsible for beginning to adapt our buildings to ensure that climate change can be stabilized" (Roaf S., Nicol.,2005). Design techniques in warm-humid climates have been studied only rarely by some Egyptians.

Climate design is essentially meant to take full advantage of nature and the design-built environment climate.

Fathy (Fathy,1977) claimed that "Over many centuries, people in every part of the world have learned how to deal with their environment through trial and error. Their solutions to the housing issue were created from countless trials and accidents, from the experience of generations of builders who preserved what worked and rejected what did not. These solutions have been passed on as tradition."

Arslan and Kumkale (2005) verified the view of Fathy that man observes nature and provides solutions to his life to live as a result of these observations and by imitating, knowing, and producing the processes in nature,

Cofaigh et al. (1996) suggested that climate architecture is a problem in many architects' minds. When most of them understand the value of working with and not against climate, the term will shift to architecture.

Hyde (2000) noted that climate-responsive architecture is an integral component of the environmental system built to reduce impacts on the environment and ensure human well-being.

Cofaigh et al., (1996) clarified that natural ventilation could be accomplished by using the benefits of night-time air and the evaporation effect of water, such as fountains and ponds is the easiest way to cool the dwelling.

Upendra Rajapaksha (2020) studied the impact of plan depth of multi-level office buildings in tropics in minimizing indoor air temperature elevation due to heat stress on the façades. Highlighted lessons were on the ways that plan form can interfere in addressing heat stress from outside.

3. Methods

The research objectives will be achieved by the research methodology, which based on three fundamental approaches, as follows:

First: The theoretical approach, which deals with identifying the climatic factors affecting the design of buildings, and the environmental needs to ensure the success of these buildings.

Second: The Analytical study approach towards urban and architectural treatments; to achieve thermal comfort rates in hot, dry, and humid areas. Criteria and guiding principles have been derived from the theoretical and analytical backgrounds and their direct impact on buildings and urban areas' design stages to achieve thermal comfort.

Third: The applied approach, which incorporates a design proposal for an urban residential complex and designing a residential building model that achieves thermal comfort rates and environmental needs in the dry and humid hot regions.

From the guiding principles and the drawn criteria from the analytical and theoretical studies, the recommendations could be applied in the future for designing residential buildings and urban complexes in hot regions.

4. Climatic factors affecting the design

Architectural solutions should secure human comfort to provide suitable architectural solutions. These factors are Solar radiation – Suitable temperature – Wind – Steam and humidity – Rainfall.

These climatic elements have been tracked in climatic data form and information through weather tracking stations, spreading throughout cities and regions. The constant measurements every hour throughout the day were converted into monthly averages in relatively long-term rates.

4.1 Environmental Needs

Human needs must be provided in the design of a building or a complex to guarantee this building or compound's success. These needs can be summarized in:

- Thermal comfort within the building defines as " the person's ability to maintain its stable temperature through a chain of thermal exchanges between the human body and the environmental factors". For this reason, the human body is considered in a state of thermal balance as it generates and loses heat.
- Comfort measurement: This is defined through a measure of the temperature – Comfort graph by Victor Olgay.

4.2 Urban and Architectural treatments to achieve comfort rates in hot regions

These have been carried out in the past, and consecutive eras have specific procedures and techniques whose success has been proved despite their simplicity. This is due to the climatic treatment, whether on the small residential unit level or the level of a civilized residential gathering in the countryside or the city. These traditional sites were confined as historical sites. The more modern urban patterns are spreading on much larger geographic areas. In modernized areas, main and local streets may reach 50 meters in width. These areas are characterized by leaving large spaces between buildings. The urban mass mostly appeared in buildings up to 5 stories high. The building's designs are like common folk residency models in the Delta cities and the Valley of the Nile. This style spread due to consulting architectural experts from advanced countries, and the blind copying by the less-developed countries. Another defect is the modern technological techniques used to create an artificially ventilated interior space; without considering the climatic factors and the countries' economic state.

4.2.1 Urban Treatments

As shown in Table 1, Five elements of the urban fabric which control the miniature climate have been specified to be studied and to reach an ideal climatic state for each of these elements, which are: Space ratios – Space entrances – Building heights, and road proportions – Orientation of the building mass – In-between distances and occupation ratios, this achieves flexibility for the designer, where he can move within it without affecting the thermal comfort, which has been achieved in the building.

Experiments have been carried out on different urban residential groupings to find the most suitable urban settlement, which achieves the lowest heat rate. Experiments were carried out upon different residential groupings using computers, showing how the wind moves and its speed and the temperature within the urban fabric, to measure the average temperature for each (Table 2) (Al-Fajal, K., 2002).

1-The linear space (Roads), 2- The yards, 3- Spaces between residential groupings

It is clear from Table 3 that the pedestrian passageways' orientation is towards the southeast and northwest, which is preferred in urban residential groupings. (Al-Fajal, K., 2002)

It has concluded from Table 4, that small, repeated courtyards are better than their larger counterparts, and putting roofs on passageways leading to lower the temperature within the courtyards. (Al-Fajal, K., 2002)

Table 1: The factors affecting the urban fabric

Proportion for spaces	Entrance for Space	High of Buildings and Road sizes	Buildings orientations	Dimensions of buildings and proportions
				<p>The facade of the building take all the land width Occupancy rate 45% Void ratio 35%</p> <p>The facade of the building take part of the land width (3/4) only Occupancy rate 45%</p>
Floor Plan		section		

Table 2: A comparison of experiments on the space between residential groupings

Building Communitie	Urban plan	Wind in main spaces	Wind on the building	Tempretuare in main spaces
Group of Buildings in 6 October city		From Zero to 1.3m/s	7442 Watt/m ²	30-37 degree
Group of Buildings in 10 Ramadan city		From Zero to 1.3m/s	5784 Watt/m ²	29-36 degree
Group of Buildings in New Menia city		From 1.7 to 3.5m/s	9978 Watt/m ²	35-40 degree

Table 3: A comparison of the linear space experiments (Roads)

measurements	1	2	3	4	5	6	7	8	9	Average
First Experience										
Airflow speed	0.82	0.34	0.83	1.06	0.27	0.90	0.87	0.35	1.46	0.76m/s
Temperatures	42.3	43.4	42.8	43.5	45.1	43.5	42.6	41.7	42.2	43.1m
Second Experience										
Airflow speed	1.94	0.56	1.99	0.99	2.26	0.99	1.09	3.99	2.37	2.23m/s
Temperatures	41.7	42.5	41.7	42.6	43	42.7	42	41.8	42	42.2m
Third Experience										
Airflow speed	3.6	4.99	5.6	3.11	3.31	1.11	5.8	6.3	6.47	4.84m/s
Temperatures	40.9	4.8	40.7	42.1	41.6	41	40.7	40.6	40.6	41m

Table 4: A comparison of courtyard space experiments

	Wind Speed	1.02	3.67	1.02	1.9m/s
	Temperatures	43.3	42.4	43.3	43m
	Wind Speed	1.66	1.32	0.58	1.18m
	Temperatures	42.3	42.5	43.2	42.66m
	Wind Speed	0.64	0.18	0.63	0.48m/s
	Temperatures	41.9	41.9	41.9	41.9m

4.2.2 Architectural treatments

The relation between buildings and their surrounding environment must be studied to be able to design a building. That is suitable for the climate and environmental needs and to achieve thermal comfort for the person living within the building; this requires considering each of the following: Building orientation – Building shape, proportions, and external dimensions – Construction material and methods – Design of the exterior cover of the building - design of the building.

A. Building orientation: The building orientation considerations in the hot climate region submit to the wind considerations more so than the sun, and under any circumstance, the building must be well ventilated. It is also essential to shade the eastern and western façades of the building.

- Wind movement around the building: The wind moves in front of the building's façade, creating areas of positive and negative pressure around the building. The air escapes to the sides where the angles of the building's edges lie. The wind current crashing into the building is separated at the ground creating whirlwinds in the shape of a horseshoe which flows around the base of the building (Figure 1) (Al-Wakeel, S.,1989)

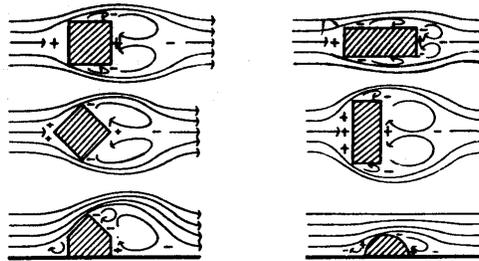


Figure 1. Air movement around the building

- Building orientation concerning the pressure areas around it: If the building façade is perpendicular to the wind movement, this increases the building's positive and negative pressure areas. It also increases the internal air movement through the mass. If the building has been oriented at angles not perpendicular to the wind, the values of the pressures around the building decreased, and consequently, the wind movement decreased. In general, the pressures around the building are varied according to the shape of the building.
- In general, the pressure around the building changes depending on the building's shape(Figure2)(Brown, G.2001).

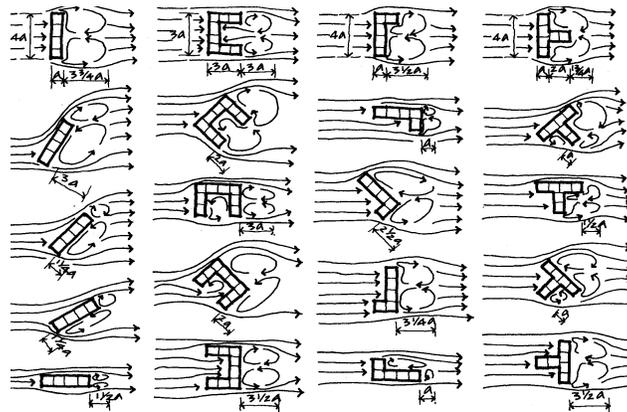


Figure 2. The difference in building shapes, proportions and, direction to wind affects the negative and positive pressure areas and thus affects the movement of air around the building and its speed

- Building orientation and effect of the sun upon it: The building orientation affects the amount of solar radiation falling upon it and the areas of pressure around the building and the wind movement. It is known as the southern façade is exposed to more solar radiation in the winter and less in the summer. In contrast, the western façade is exposed to a massive amount of solar radiation during the summer. The building orientation's effect appears in the amount and shape of shadows as portrayed in Figure 3.

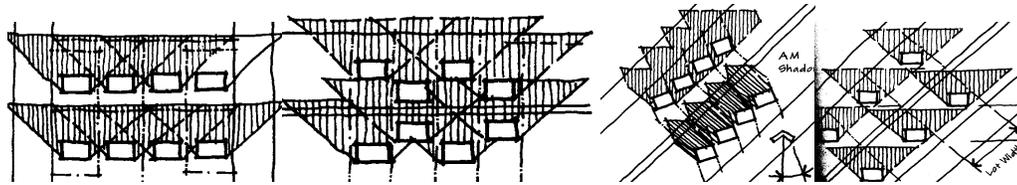


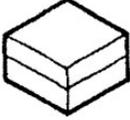
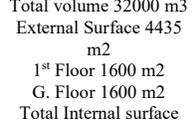
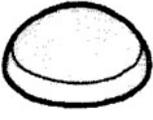
Figure 3. The shape and quantity of shadows vary according to the building orientation and grouping

B. Building shape and proportions:

• Building shape:

In the case of building block shape, which is usually designed to achieve the lowest exposure of the external surfaces to solar radiation, with the internal space's size. Table 5 is representing a comparison of several blocks; of uniform size and different shapes. The block with a spherical cap has the least external area exposed to solar radiation. Therefore, it is preferable to use domes to cover buildings in hot regions (Hamouda.N., 2002).

Table 5: Comparison of three building blocks of uniform size and different shapes

Building Form Cube		Building Form Cylinder		Building Form Sphere	
Total volume 32000 m3		Total volume 32000 m3		Total volume 32000 m3	
External Surface 4800m2		External Surface 4435 m2		External Surface 2864 m2	
1 st Floor 1600 m2		1 st Floor 1600 m2		1 st Floor 1618 m2	
G. Floor 1600 m2		G. Floor 1600 m2		G. Floor 1932 m2	
Total Internal surface 3200m2		Total Internal surface 3200m2		Total Internal surface 3550m2	

- Building proportions and dimensions: are directly affecting the amount of the received solar radiation. The ideal ratio for building elongation in hot regions is 1: 1.3 and may increase to 1:1.6, and by the deployment of the mass and creating an interior yard; the surfaces facing north increase and the shade increases on the facades and the yard's surface. So, it is preferred to orient the rectangular building towards the east-west, to have the largest area of façade possible facing north while having a good distribution of the necessary building's spaces which require suitable thermal and lighting conditions.

C. Methods of construction and building materials.

- Materials of low thermal conductivity are suitable for decreasing the temperature within the building.
- It is preferred to use finishing materials of light colors, reflecting solar rays, leading to a temperature decrease within the building during the summer.
- It is preferred to utilize a double ceiling, which contains a space between its parts; (Figure 4 this is for a wind current to pass through it which achieves continuous ventilation around the building. (Wakil, S. 1989)
- It is preferred to use local natural materials like Limestone, sandstone, and mud in a special architectural fashion, while at the same time making sure that the building complies with hot climate conditions.

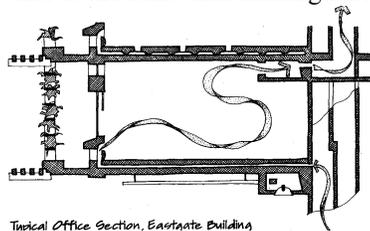


Figure 4. The double roof is used to reduce heat penetration and protect the building from solar radiation and was developed and used in the building's ventilation

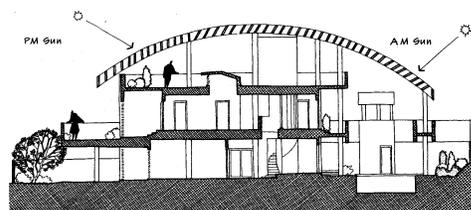


Figure 5. Using a double ceiling in a modern way to reduce heat in a house in Malaysia

D. Outer Cover of the Building

- There are many ways to protect the building body (its walls, openings, and surfaces) from solar radiation; by creating protrusions for the floors as we go upwards to provide suitable sunlight blockers in front of the openings

by using arcades in the ground level to protect pedestrians.

- Designing double roofs is used in Malaysian houses in a new way, using roofs as gardens (Figure 5) and homes in India (Figure 6). (Wakil, S.,1989)
- Using curved ceilings to provide wind action which transfers heat away from the interior space.
- Designing shading methods: to control the sunlight penetration into the building during the winter, and prevent it during the summer, protrusions has been used according to the angles of the sun in winter and summer (Figure 7) (Hamouda, N., 2002).
- Shape and position of building openings: The areas of positive and negative pressure around the building increase in the case of closing the openings, and the wind motion within the space begins when suitable openings are provided, which in turn move from areas of negative pressure behind the building (Figure 8) (Wakil, S.,1989),
- All the living spaces must include at least two external openings, as one of them is for the wind to enter and the other for the wind to exit. (Figure 8)
- Using large and high openings that extend from the floor to the ceiling in the wind's motion, and due to summertime being long in these regions, moving upper windows which utilize the ventilation operation is preferred while taking into consideration to protect them from sunlight.

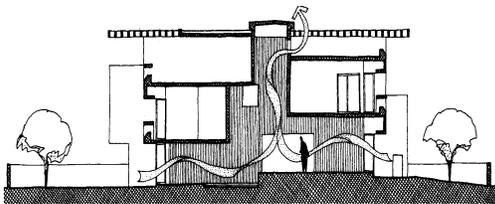


Figure 6. Using a double roof and creating a roof garden as an architectural solution

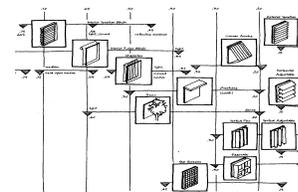


Figure 7. different shapes of the solar panels according to the angles of the sun on the various facades

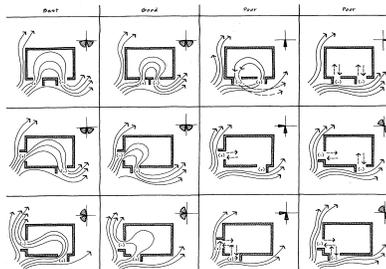


Figure 8. shows the effect of the different locations, number, and locations of openings on air movement inside and outside the building

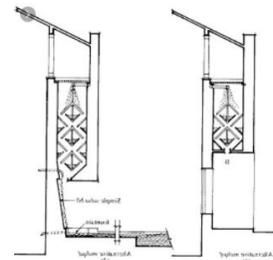


Figure 9. Wind Towers and their impact To ventilate buildings throughout the day

4.2.2.1 Building Design

When designing buildings in regions of the hot climate, it is essential to utilize some design vocabulary of hot climate regions, which are:

- Wind towers: As known in most countries of the hot climate in the Islamic world starting from Pakistan, Iran, Iraq, and the countries of the Arabian Gulf, to Egypt and the North-African countries, even with the difference in general look and construction details from one country to another the main goal is the same which is to achieve a current of natural wind for ventilation and cooling within the building. Several types of wind towers are represented in Figure 9. The examples of application include the usage of wind towers in Qatar university in Al-Doha (Figure 10), and in an Iraqi home (Figure 11). The application of wind towers is not limited to countries with a hot climate, but they have been used for ventilation in European countries like England. They were found suitable for the climatic conditions in the "Queen's building" in Montfort university.(Figure 12)Wind towers have been developed to be ideal for the age and merging modern technology with traditional elements (Figure 13).

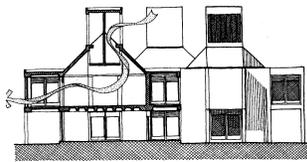


Figure 10: Using wind towers in the university building in Doha

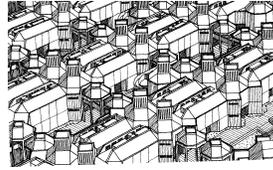


Figure 12: Using wind towers in cold countries as a thermostat as in England.

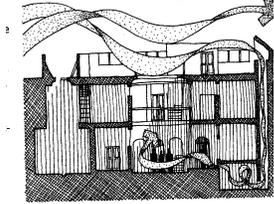


Figure 11: One of the Iraqi dwellings where the grab was used in the process of internal ventilation.

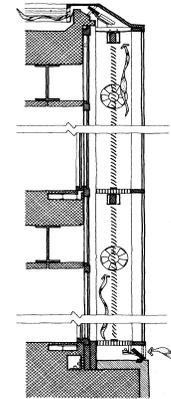


Figure 13: Introduction of modern technology in wind towers to give higher efficiency and keep pace with technological progress

- Inner courtyards: open courtyard or yard is considered the main space for social activity In hot climate areas, and it is the main space that affects the physiological state where protection from external noise and pollution and natural lighting is allowed, besides it being a thermal regulator, as it cools the surfaces overlooking it at night through cool nightly radiation which is stored within it the entire night, and so the air temperature decreases about 2 to 5 degrees Celsius from the external air during the period before and afternoon according to the degree of its containment and treatment. (Koyan, A.1984) (Figure 14)

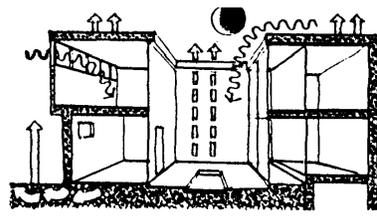
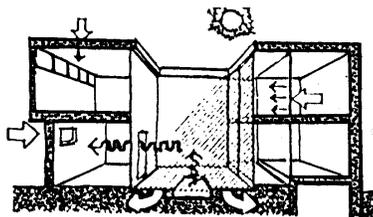


Figure 14. As a thermostat during the day, the courtyard stores heat energy during the day and transmits it at night to warm the atmosphere. The patio is like a thermostat at night as it stores cold air and the surface of the courtyard radiates the amount of energy the courtyard acquired during the day. (Koyan, A.1984)

5. Results and Discussion

5.1 A Proposed Design for an Urban Compound and a Residential Building which achieves comfort rates and suits environmental needs:

A. Suggestion for a residential Building (Figure 15)

- The model is a vertically ground floor with the potential for vertical extension. It contains an inner patio and a parking lot. The building's orientation is north-south, and the east and west facades overlook the courtyard, so the rest of the building block shades it.
- All the living spaces contain two external openings for ease of the ventilation process.
- The inner yard contains a water surface and trees to increase the humidity within the residence.
- Using double walls in the external walls.
- Using a double ceiling to protect the building from solar radiation.

B. Proposed Design for an Urban Compound (Figure 16)

- The residential compound complex is designed so that the pedestrian paths are in easterly, western, and refracted directions to provide shadows and to better distribute the airspeeds in them.
- A separation between pedestrian and traffic movement was made for ease of climatic handling. In the proposed design, the ground's occupancy rate was reduced to 85%, to reduce the temperature of the air permeating the

spaces between them. Courtyards are added to the structural blocks to reduce the occupancy rate. The average air velocities increase in the areas surrounding the connected building blocks, and thus the air temperature decreases.

- Buildings are placed in two-story rows to increase the desired airflow.
- Quenching corridors create a sequence of shadows and light, which reduces the temperature by 3.5 degrees Celsius in open spaces.

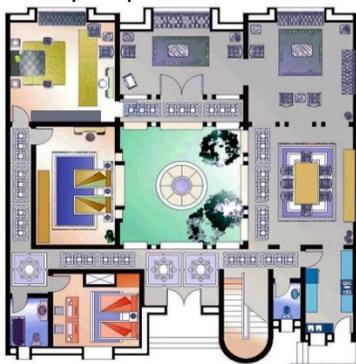


Figure 15. Suggestion design for residential building achieves comfort rates



Figure 16. A suggestion for an urban compound-site plan for the compound

5.2 Proposed Improvements Recommendations regarding the urban design

- It is preferred that the pedestrian passageways be in eastern-western directions and discontinuous to provide shade and better distribution of wind speeds within it.
- Pedestrian movement and mechanism movement must be separated for ease of climatic treatment
- Lowering building heights from four stories to two (A street section from 1: 10 to 1:8) increases the average wind velocity by 30%, decreasing the wind temperature by 0.7 m.
- By increasing the area of ground occupied to 85%, the temperature of the wind leaking through the spaces between increases, and by adding open courtyards to building masses, the percentage of occupation decreases and the average wind speeds increase in the areas surrounding the connected building masses and so the temperature decreases.
- The previous experiments show the importance of placing buildings in connected rows at the height of two stories to increase the desired wind's blowing.
- The importance of segmented shading of passageways with roofs, to create a sequence of shade and light. This contributes to lowering the temperature by 3.5 degrees Celsius in comparison to an unshaded version.
- In the case of multiple passageway openings for space, this helps with the motion of wind trapped between the building mass and space.
- Non-energy-consuming urban structures are built, and local construction materials are used in their natural colour and texture while being developed.
- Not exaggerating the width of the external spaces as intense sun rays prevent its utilization in performing activities.
- Small repeating spaces are better than one large space.
- Heading for an old, connected, horizontal urban style, based on the idea of a courtyard community, and residences with inner courtyards to regulate the temperature throughout the day.
- The orientation of the urban mass and internal passageways allow shades to be available most of the daytime. They were also taking into account the sun's vertical and horizontal angles throughout the year.
- Based on the analysis of hot climate, the importance of using trees within the urban fabric with high density is evident, as well as using limited water surfaces to lower the temperature and raise the air's humidity level to reach a partial climate suitable for life and work.

5.3 Proposed Improvements Recommendations regarding the Architecture Buildings

- Directing the building to be perpendicular to the prevailing wind increases wind passing through the building and decreases the temperature.
- Directing the building to achieve the most significant amount of shade possible.
- Using light-coloured finishing materials to help reflect sunlight, decreasing the temperature within the building.
- Using a double ceiling which leaves a space between its layers.
- Using local building materials and using heat insulating or non-heat-conducting materials.
- Using wind towers and inner courtyards when designing decreases the amount of temperature within the building in the summer and stores heat in the winter.
- All the living spaces must include at least two external openings, one for the wind to enter and the other for it to exit.
- Using sunlight shutters according to the angles of the falling sunlight on the different facades to decrease the thermal radiation within the building
- Decreasing the external cover area percentage reduces thermal gain in the summer and decreases thermal loss in the winter.

6. Conclusion

- All objectives have been met and emphasized of unique research contribution (10 lines). The climatic factors affecting the building and the community's design were identified to choose the appropriate solutions. These factors are harmonious with thermal comfort and provide the proper conditions for the individual inside the building. Thus, it was ensured that the human needs for adequate thermal comfort were provided inside the building and the residential complex to ensure the design's success.
- Reaching treatments and urban fabric elements, which are divided into void ratios - void entrances - building heights and road ratios - building mass orientation - intermediate distances and occupancy rates. The purpose is to provide flexibility for the designer by choosing the appropriate treatment to achieve thermal comfort within the building complex.
- Affording architectural treatments that lead to the building's compatibility with the surrounding environment. Thus, reaching a building design that commensurates with the climate and environmental needs. Also, achieving thermal comfort for humans inside the building requires considering all of the following: Building orientation- Building shape, proportion, and external dimensions- Different building materials and construction methods- Designing the exterior envelope of the building- Building design.
- From the study of the humanitarian needs and the identification of climatic factors in hot regions, the climatic problems facing cities and buildings in hot areas were addressed. By relying on the urban and architectural treatments generated by research; it was possible to achieve the requirements of the environmental aspects and provide thermal comfort inside the proposed residential design project, and within the proposed residential complex.
- Offering a set of propositions and foundations for structural and urban treatments and proposing them for future use.

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Biography

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