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# *Thermal Comfort Strategies for the City of Hurghada*

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**Abstract**

Climatic data analysis aims at deciphering the different environmental factors that architects face when designing a building at a certain location. However, these factors can be magnified or diminished by other natural settings such as topography and surrounding landscape. In this work, the different environmental and natural factors affecting the city of Hurghada are analyzed and various design strategies are evaluated, with the aim of obtaining the most efficient design strategies for achieving thermal comfort. The resulting strategies can be used by architects and decision-makers when assessing the different building design options for future development projects in the city of Hurghada.

**Keywords:** Thermal Comfort, Hurghada

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# 1. Introduction

## 1.1. Overview

The city of Hurghada is a typical example for hot humid climate, since it is located on the edge of the hot Sahara desert and the coast of the Red Sea. It's one of the most famous destinations for beach tourism in the Middle East. Moreover, it became home to a large foreign population reaching almost 20,000 permanent residents who decided to make the warm beach their home (Al-Masry Al-Youm, 2020). However, the architecture of Hurghada rarely addresses its climate in a positive way. Most resorts and hotels depend on artificial HVAC systems to provide comfort for their guests rather than presenting an architecture that adapts to climatic factors. In the coming sections recommended approaches will be generated and discussed, starting by knowing more information on the city and its surroundings.

Table1. Location of the city of Hurghada

| **Attribute** | **Number** |
|---|---|
| Latitude | 27.2389 |
| Lat. (DMS) | 27°14' 20N |
| Longitude | 33.8361 |
| Long. (DMS) | 33° 50' 10E |
| Altitude (feet) | 72 |
| Alt. (meters) | 21 |

## 1.2. Geography of Hurghada

Hurghada is a coastal harbor-city, full of sand beaches and ports. Off the coast, the city boasts of an exotic reef teeming with colorful and varied marine life. The city of Cairo, which is the capital of Egypt, is located some 530 Km north of Hurghada and Luxor, another Egyptian hub, lies 290 Km west of it. Hurghada is located on the coast of the Red Sea, which is known to be one of the world's warmest seas (Romanelli, 2018), allowing water sports most of the year.

## 1.3. Topography of Hurghada Area

Hurghada lies on a sea valley, 21m above sea contained between the Red Sea on the East and North-East, and the series of Red Sea mountains to the West and South-West (Moawad, 2013). This topography provides sea breeze from the North-East and regions to the left. At the same time, the mountains store thermal energy in the morning and release it at night, adding to the complexity of the climate of the region.

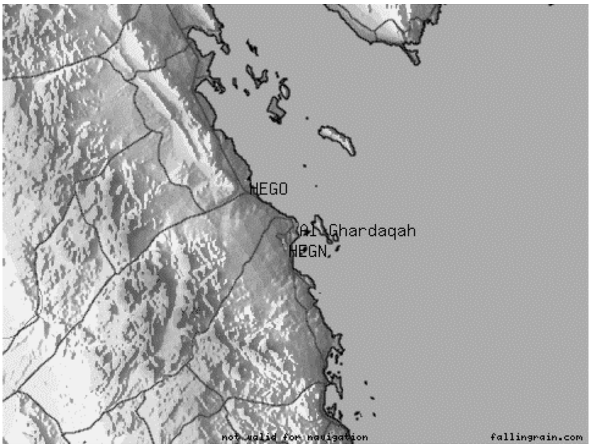


Fig.1: Hurghada's topography on the Red Sea Coast, East of Egypt (FallingRain, 2022)

The first glance at the location of the city of Hurghada suggests that it is a case of hot-humid climate that requires a design which can decrease humidity, decrease heat gain, and provide cross-ventilation. However, combining geographical and topographical information, one can notice that the prevailing wind actually comes from NW which primarily consists of sand dunes and a mountainous plateau. This fact means that when wind is active, the atmosphere of the city is predominantly dry as it has passed through sand dunes and hot mountains before finally arriving at the city buildings. It is also worth noting that during spring, the mountains to the south-west of the city block the hot dusty wind -that many times can lead to sandstorms- providing a natural line of defense for the city. However, whenever the wind direction changes, or it becomes too weak to make a difference, the moisturized breeze coming from the sea prevails. This complexity means that the most efficient design approach should be a combination of different green design strategies rather than a single one.

## 2. Suggested Strategies

In this section Victor Olgyay's Psychrometric Chart is used to identify the different strategies that can lead to thermal comfort given the climatic data of the city. The graph in Fig.2 shows the selected design strategies to achieve thermal comfort, being:

- Passive Solar Heating (for under-heated region)
- Exposed Mass + Night Purge Ventilation (for dry/humid overheated region)
- Natural Ventilation (for humid overheated region)

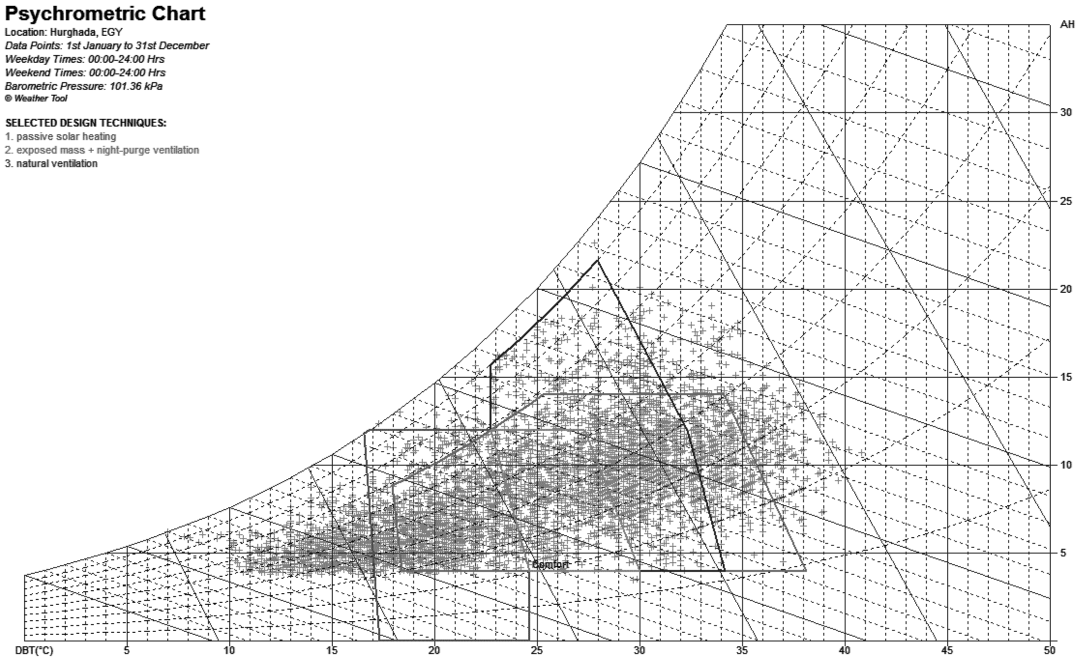


Fig.2: Psychrometric chart showing the suggested design strategies.

The selected design strategies cover most of the hourly data points, leading to comfort levels most of the year. This means that a design approach that combines these strategies will be the most efficient and effective one in achieving thermal comfort for users.

## 3. Analysis of Strategies

In this section, the selected techniques will be analyzed, in order to get the most out of them. The definition, advantages and disadvantages of each of them will be tackled respectively.

### 3.1. Passive Solar Heating

3.1.1. Definition

Passive solar energy is the direct use of heat inside a space, utilizing the design of the building so as to trap solar heat and use it for different purposes (Cremers & Binder, 2016). This means that the passive solar design ensures that the house is not too cold during winter and not too hot in the summer (DOE, 2022). Passive solar buildings are designed to let the heat into the building during the winter months, and block out the sun during hot summer days (Fosdick, 2016).

3.1.2. Advantages

- Free heating in winter

- No fossil fuels needed
- Clean and direct use of energy

3.1.3. Disadvantages
- Needs special architectural design
- Need equipment to be transferred to all spaces such as Solar Tubes

### 3.2. Exposed Mass + Night Purge Ventilation
3.2.1. Definition

Exposing mass means having a bigger outer skin with respect to the volume of the building. The phrase 'purge ventilation' has been introduced as a reworking of the previous 'rapid ventilation' which relates to specific and intermittent ventilation required to clear air of paint fumes, vapor from heaters, cooking smells, etc. (Williams, 2006). In BREEAM there is a requirement for purge ventilation in sanitary accommodation. For example, it recommends that there be a clear opening area equivalent to 1/20th floor area, catered for by a fully operable window(s), regardless of the mechanical, passive or trickle ventilation requirements provided (Hammersmith & Fulham, 2022).

3.2.2. Advantages
- Free of charge cooling
- Losing heat fast
- Flattens humidity curve through day

3.2.3. Disadvantages
- Does not work with all spaces
- Needs special architectural design

### 3.3. Natural Ventilation
3.3.1. Definition

Natural ventilation can be described as a process for providing fresh air movement within an enclosure by virtue of air pressure differentials caused primarily by the effects of wind and temperature variations in and around the enclosure (Whittleton & Wood, 2002). There are two types of natural ventilation occurring in buildings: wind driven ventilation and stack ventilation. The pressures generated by buoyancy, also known as 'the stack effect', are quite low (typical values: 0.3 Pa to 3 Pa) while wind pressures are usually far greater (~1 Pa to 35 Pa) (Bhatia, 2014). The majority of buildings employing natural ventilation rely primarily on wind driven ventilation, but stack ventilation has several benefits. The most efficient design for a natural ventilation building should implement both types of ventilation (Etheridge, 2012).

3.3.2. Advantages
- Free of charge cooling
- Healthier than mechanical ventilation
- Refreshes oxygen levels inside space

3.3.3. Disadvantages

- May let airborne pollution enter the building
- Needs certain types of windows to control air flow

## 4. Outer Envelope Treatment

In this section, different treatment options for the outer envelope will be illustrated, in order to select the most efficient one. Note that these suggested cross-section design options are re-designs of the widely-used materials in Hurghada, with minor changes.

### 4.1. Walls

Table2. Different combinations of wall cross-sections and their thermal performances

| Layer | Conduct. ( Energy Code) W /m°C | Resist. m°C/ W | Wall A | | Wall B | | Wall C | | Wall D | | Wall E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Thick. (m) | R | Thick. (m) | R | Thick. (m) | R | Thick. (m) | R | Thick. (m) | R |
| Cement Plaster (Internal) | 0.175 | 5.71 | 0.02 | 0.11 | 0.02 | 0.11 | 0.02 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gypsum Plaster | 0.15 | 6.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.13 | 0.02 | 0.13 |
| Dense Bricks | 0.6 | 1.67 | 0.12 | 0.20 | 0.25 | 0.42 | 0.24 | 0.40 | 0.24 | 0.40 | 0.24 | 0.40 |
| Air Cavity | As in Code | As in Code | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polystyrene | 0.034 | 29.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.59 | 0.05 | 1.47 |
| Cement Plaster (External) | 0.175 | 5.71 | 0.02 | 0.11 | 0.02 | 0.11 | 0.02 | 0.11 | 0.02 | 0.11 | 0.02 | 0.11 |
| Sub-Total | | | 0.16 | 0.43 | 0.29 | 0.65 | 0.53 | 0.84 | 0.30 | 1.24 | 0.33 | 2.12 |
| Int. Air Film (Surf. Resist.) 5th Floor | | | -- | 0.123 | -- | 0.123 | -- | 0.123 | -- | 0.123 | -- | 0.123 |
| Ext. Air Film (Surf. Resist.) 5th Floor | | | -- | 0.055 | -- | 0.055 | -- | 0.055 | -- | 0.055 | -- | 0.055 |
| TOTAL RESISTANCE m$^{2o}$C/W | | | | 0.61 | | 0.82 | | 1.02 | | 1.41 | | 2.30 |
| U-value | | | | 1.65 | | 1.21 | | 0.98 | | 0.71 | | 0.44 |

### 4.2. Roofs

Table3. Different combinations of roof cross-sections and their thermal performances

| Layer / Thickness | Conductivity (Energy Code) W/m ºC | Resistivity mºC/W | Roof A | | Roof B | |
|---|---|---|---|---|---|---|
| | | | Thick. (m) | R | Thick. (m) | R |
| Cement Tiles | 0.175 | 5.71 | 0.025 | 0.143 | 0.025 | 0.143 |
| Cement Mortar | 0.175 | 5.71 | 0.025 | 0.143 | 0.025 | 0.143 |
| Sand | 0.35 | 2.86 | 0.050 | 0.143 | 0.050 | 0.143 |
| OC | 0.175 | 5.71 | 0.075 | 0.429 | 0.075 | 0.429 |
| RC | 0.175 | 5.71 | 0.150 | 0.857 | 0.150 | 0.857 |
| Bitumen | 0.17 | 5.88 | 0.020 | 0.118 | 0.020 | 0.118 |
| Polystyrene | 0.034 | 29.41 | 0.050 | 1.471 | 0.000 | 0.000 |
| Gypsum | 0.15 | 6.67 | 0.025 | 0.167 | 0.020 | 0.133 |
| Sub-Total | | | 0.420 | 3.469 | 0.365 | 1.965 |
| Int. Air Film (Surf. Resist.) 5th Floor | | | | 0.104 | | 0.104 |
| Ext. Air Film (Surf. Resist.) 5th Floor | | | | 0.045 | | 0.045 |
| TOTAL RESISTANCE $m^{2o}C/W$ | | | | 3.618 | | 2.114 |
| U-value | | | | 0.276 | | 0.473 |

The use of Polystyrene (in case of walls/roofs) and double walls with an air cavity in between (in case of walls) have a decisive role in achieving a high resistance (and low heat transfer coefficient) in compliance with the Egyptian Energy Code (Gaafar, 2021).

## 5. Shading Treatment

In this section, the different shading treatment options are tackled. In order to reach the best shading solution, the issues of solar radiation and hence optimum orientation are discussed.

### 5.1. Solar Radiation

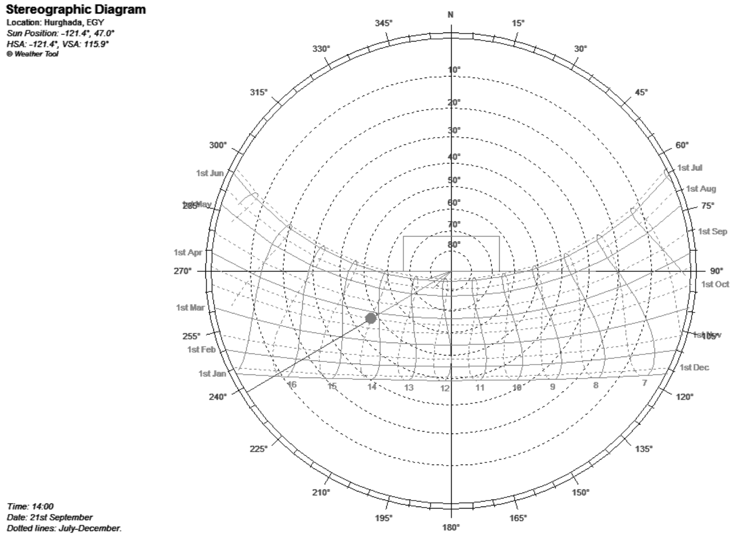


Fig.3: Annual solar path for the City of Hurghada with special emphasis on the position of the Sun at 14:00 hrs. (Source: Fallingrain.com)

The solar path diagram for Hurghada, Egypt (27° 14') shows a mild northern hemisphere path with long daytime during summer and relatively shorter during winters. Highest solar radiation detected at noon during all year, resulting in max air temperature at about 2PM without taking cloud cover into account.

Table4. Solar data for the city of Hurghada.

**Tabulated Daily Solar Data**

Latitude: 27.1°
Longitude: 33.7°
Timezone: 30.0° [+2.0hrs]
Orientation: 105.0°

Date: 18th June
Julian Date: 169
Sunrise: 04:55
Sunset: 18:37

Local Correction: 13.7 mins
Equation of Time: -0.9 mins
Declination: 23.4°

| Local | (Solar) | Aziumuth | Altitude | HSA | VSA |
|---|---|---|---|---|---|
| 05:00 | (05:13) | 64.1° | 1.0° | -40.9° | 1.3° |
| 05:30 | (05:43) | 67.3° | 7.1° | -37.7° | 8.9° |
| 06:00 | (06:13) | 70.3° | 13.3° | -34.7° | 16.0° |
| 06:30 | (06:43) | 73.1° | 19.6° | -31.9° | 22.8° |
| 07:00 | (07:13) | 75.8° | 26.1° | -29.2° | 29.3° |
| 07:30 | (07:43) | 78.3° | 32.6° | -26.7° | 35.5° |
| 08:00 | (08:13) | 80.9° | 39.1° | -24.1° | 41.7° |
| 08:30 | (08:43) | 83.5° | 45.7° | -21.5° | 47.8° |
| 09:00 | (09:13) | 86.2° | 52.4° | -18.8° | 53.9° |
| 09:30 | (09:43) | 89.2° | 59.1° | -15.8° | 60.0° |
| 10:00 | (10:13) | 92.9° | 65.7° | -12.1° | 66.2° |
| 10:30 | (10:43) | 98.0° | 72.4° | -7.0° | 72.5° |
| 11:00 | (11:13) | 107.1° | 78.9° | 2.1° | 78.9° |
| 11:30 | (11:43) | 134.5° | 84.8° | 29.5° | 85.4° |
| 12:00 | (12:13) | -139.4° | 85.2° | 115.6° | 92.1° |
| 12:30 | (12:43) | -108.2° | 79.4° | 146.8° | 98.9° |
| 13:00 | (13:13) | -98.5° | 72.9° | 156.5° | 105.7° |
| 13:30 | (13:43) | -93.3° | 66.3° | 161.7° | 112.6° |
| 14:00 | (14:13) | -89.5° | 59.6° | 165.5° | 119.6° |
| 14:30 | (14:43) | -86.4° | 52.9° | 168.6° | 126.5° |
| 15:00 | (15:13) | -83.7° | 46.3° | 171.3° | 133.4° |
| 15:30 | (15:43) | -81.1° | 39.7° | 173.9° | 140.2° |
| 16:00 | (16:13) | -78.6° | 33.1° | 176.4° | 146.8° |
| 16:30 | (16:43) | -76.0° | 26.6° | 179.0° | 153.4° |
| 17:00 | (17:13) | -73.3° | 20.2° | -178.3° | 159.8° |
| 17:30 | (17:43) | -70.5° | 13.8° | -175.5° | 166.2° |
| 18:00 | (18:13) | -67.6° | 7.6° | -172.6° | 172.4° |
| 18:30 | (18:43) | -64.4° | 1.5° | -169.4° | 178.5° |

**Tabulated Daily Solar Data**

Latitude: 27.1°
Longitude: 33.7°
Timezone: 30.0° [+2.0hrs]
Orientation: 105.0°

Date: 24th December
Julian Date: 358
Sunrise: 06:36
Sunset: 16:53

Local Correction: 15.3 mins
Equation of Time: 0.6 mins
Declination: -23.5°

| Local | (Solar) | Aziumuth | Altitude | HSA | VSA |
|---|---|---|---|---|---|
| 07:00 | (07:15) | 119.4° | 4.7° | 14.4° | 4.9° |
| 07:30 | (07:45) | 123.3° | 10.4° | 18.3° | 10.9° |
| 08:00 | (08:15) | 127.6° | 15.8° | 22.6° | 17.1° |
| 08:30 | (08:45) | 132.5° | 21.0° | 27.5° | 23.3° |
| 09:00 | (09:15) | 137.9° | 25.7° | 32.9° | 29.8° |
| 09:30 | (09:45) | 144.1° | 29.9° | 39.1° | 36.5° |
| 10:00 | (10:15) | 151.0° | 33.5° | 46.0° | 43.6° |
| 10:30 | (10:45) | 158.6° | 36.3° | 53.6° | 51.1° |
| 11:00 | (11:15) | 166.9° | 38.3° | 61.9° | 59.2° |
| 11:30 | (11:45) | 175.6° | 39.3° | 70.6° | 67.9° |
| 12:00 | (12:15) | -175.5° | 39.3° | 79.5° | 77.5° |
| 12:30 | (12:45) | -166.7° | 38.3° | 88.3° | 87.8° |
| 13:00 | (13:15) | -158.5° | 36.3° | 96.5° | 98.8° |
| 13:30 | (13:45) | -150.8° | 33.4° | 104.2° | 110.3° |
| 14:00 | (14:15) | -144.0° | 29.8° | 111.0° | 122.1° |
| 14:30 | (14:45) | -137.8° | 25.6° | 117.2° | 133.7° |
| 15:00 | (15:15) | -132.4° | 20.9° | 122.6° | 144.7° |
| 15:30 | (15:45) | -127.5° | 15.7° | 127.5° | 155.1° |
| 16:00 | (16:15) | -123.2° | 10.3° | 131.8° | 164.8° |
| 16:30 | (16:45) | -119.3° | 4.6° | 135.7° | 173.6° |

In summer, the readings of 4pm are taken into consideration in order to provide shading that protects the building for the longest period, while in winter the readings of 2pm are observed so that the shading devices do not block warming sun rays after that time.

## 5.2. Optimum Orientation

The optimum building orientation is chosen on the basis of achieving the least solar radiation during overheated months, and the maximum solar radiation during under-heated months. For the city of Hurghada, the optimum orientation is found to be North-South with a 2.5° tilt counter-clockwise.

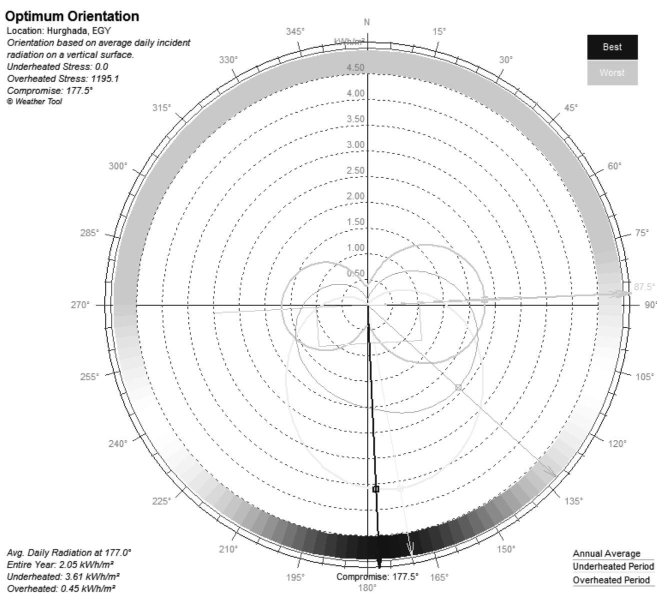


Fig.4: Calculated optimum orientation for the city of Hurghada.

### 5.3. Shading Devices

According to tabulated solar data for Hurghada on 18 Jun (representing the summit of summer), shading devices should be installed in order to prevent sunlight from heating the building up to 4pm. While on 24 Dec (representing the summit of winter) shading devices should only be designed to prevent sunlight up to 2pm only in order to allow warming sunlight after that time to enter the house. Also, solar impact analysis shows that the façades with highest solar radiation at 4pm and 8am are: Roof (1024 Watt/m2) and Eastern & Western façades (635 Watt/m2).

In the light of the above analysis, the outer envelope design shall tackle the appropriate building skin, in order to provide the best shading and orientation as described in the previous section. This given envelope design focuses on:

- Long Sunbreakers for Summer at West & East façades
- Roof Cover for Summer to eliminate huge direct solar impact
- Shorter Sunbreakers for Winter or Trees (esp. in South façade)
- Longest side facing North to achieve optimum orientation
- West and East Façades as small as possible to decrease solar impact in summer.
- The use of horizontal sunbreakers is better during noon (11am-1pm) while the use of vertical sunbreakers is better during the beginning and the end of the day during summer.

## 6. Final Results

The design aspects expressed herein can therefore lead to unique designs achieving optimum environmental performance through:

- Least Solar Exposure (Summer)
- Least Heat Gain (Summer)
- Passive Solar Heating (Winter)
- Adequate Insulation
- Cross Natural Ventilation
- Night Purge Cooling

## Conclusion

It is to be concluded that solar radiation analysis can help designers to develop building designs that are more energy efficient and in harmony with environmental conditions such as solar radiation and thermal transfer. Using computer software and accurate solar impact readings helped a lot in diagnosing the problem and identifying the appropriate tools to reduce solar impact using sheds and sunbreakers, horizontal and vertical.

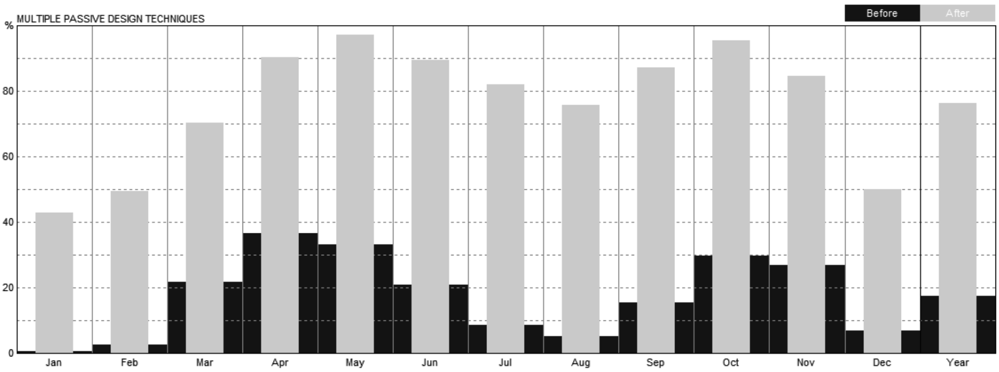


Fig.5: Comparison between comfort percentages before and after application of approaches.

The suggested design approach can greatly increase the percentage of thermal comfort hours yearlong. The above figure shows a significant increase in thermal comfort in all months, especially Aug, May, Jan and Feb, plus a significant overall thermal comfort increase on year's average. Analysis of chosen techniques also show the applicability of the chosen approaches using simple design strategies and equipment for utilization in Hurghada, Egypt.

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