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GUIDELINES AND CRITERIA FOR ENHANCING THERMAL COMFORT IN RESIDENTIAL AREAS, PORT-FOUAD, EGYPT

Magdy El-Bastawisy, Wagih Fawzy, Ashraf El-Moqadem and Arch. Naglaa Megahed

Department of Architiecture and Urban Planning, Faculty of Engineering,
Suez Canal University, Port Said

1. ABSTRACT

The main concern of this paper is providing planning and design guidelines and criteria for enhancing thermal comfort in residential areas, Port-Fouad Town, Egypt. The analysis of the case study, ancient residential area, was assessed along with micro and macro climate conditions to define the most appropriate residential planning and design guidelines and criteria in relation to the environment to enhance thermal comfort and, in turn, satisfy occupants. Results indicated that satisfaction, particularly during summer time with hot humid climate, could be achieved by using passive cooling and natural ventilation methods, as a part of building technology system. Impact of building technology on thermal comfort, moreover, was also analyzed to define guidelines and criteria for residential areas. Natural ventilation and shading control methods, as a result, are the suitable building technology systems for maintaining thermal comfort in residential areas in Port-Fouad.

2. INTRODUCTION

Port-Fouad has a unique location. It is situated on the Mediterranean Coast at the northeast corner of Egypt, eastward Port-Said city at the main entrance the waterway of Suez Canal. Port-Fouad is one of the five districts that form Port-Said Governerate, one of the three governerates (Port-Said, Ismailiah and Suez) that define Suez Canal Region, Figures 1, 2 and 3.

Although Port-Fouad is a suburban district of Port-Said City, it is called Port-Said's twin city. Port-Fouad was separated from Port-Said city by the waterway of Suez Canal in 1869. Port-Fouad, until the beginning of the 1980s, was a part of Sinai peninsula and, in turn, Asian continent. During the 1980s, Port-Fouad was segregated from Sinai Peninsula by establishing the new eastern waterway channel of Suez Canal. Currently, Port-Fouad town is an island. It is surrounded by the Mediterranean in the north, and the waterway of Suez Canal and the new eastern channel, to the west, south and east. The rest of Port-Fouad district is located in Sinai Peninsula, Figures 1, 2 and 3. Both the island and rest of Port-Fouad are connected to Port-Said and Sinai by a ferryboat system, [1].

Port-Fouad was established in 1926 to accommodate different categories of the employees of the Suez Canal Authority. About 25 % of the total land of Port-Fouad was inhabited by the employees. Port-Fouad original plan had been developed by the French Architects: Hanser and Roucou, with European building style and based on the notion of utopian socialism, [2]. Currently, Port-Fouad could be divided into two main zones: a) old zone including the original houses of the Suez Canal Authority with Europeans style; b) newly developed zone which includes different parts with sprawl building style, Figure 4. This urban development has led to significant gab between the two zones, in terms of the aspects of urban vocabulary: pattern, style, vision, etc.

Port-Fouad district extends over an area of approximately 512 square kilometers. The area of Port-Fouad is about 38 percent of Port-Said Governerate. The inhabitable area is 3 sq km. The total population size was 61000 in 1996 and estimated at 66618 in 2003. Port-Fouad, therefore, represents a relatively large and significant part of the administrative and political system at the national, regional and local levels. Port-Fouad, consequently, is facing economic interests at the national level, which are ongoing.

These economic interests include the establishment of the new eastern port, Port-Said industrial zone, El-Salam Canal, ring road around Port-Said, new bridge over the Suez Canal, new villages of Sahel Al-Tinah, new tunnel south Port-Said and development of widening Suez Canal Waterway. This development is a part of the regional and national policies provided for the development of the Third Region, Sinai Peninsula and Suez Canal Region. It is estimated that the employees of that area will reach 500000, with total population of 1.5 million persons. Port-Fouad is one of the main inhabitable districts that expected to be targeted by the employees and population growth. The share of Port-Fouad is estimated at 0.25 million, in addition to the current population size. Port-Fouad, therefore, is expected to face high rate of spatial growth, particularly with residential buildings.

Within this context, if the economic development will not be well designed, planned and managed; urban environment of Port-Fouad will be adversely affected by the new building types, which have been developed for five decades. These buildings have been developed just to fulfill the increasing demand for residential apartments during the last few decades, without any consideration to environmental aspects at all levels of development. Therefore, they do not provide any environmental satisfactory of energy saving, thermal comfort and vision, [1].

The location of Port-Fouad is reflected on its physiography and climate. Its climate could be described as Mediterranean. The macroclimate could be described as hot humid, with average percentage of humidity of 71.6, and average maximum temperature of 25.4 centigrade and average minimum temperature of 17.6 centigrade. The microclimate is highly influenced by the location of Port-Fouad, which surrounded by massive size of water surfaces. This location is reflected on the climate of Port-Fouad, which described as Mediterranean and warm humid zone, with humidity of 14%, [3]. This characteristics considered the major issue for achieving thermal comfort. This also reflected on the percentage of humidity and, in turn, on the thermal comfort of the inhabitants of Port-Fouad, especially with low wind speed.

The other main Environmental issue stands against the new residential development pattern in Port-Fouad is using mechanical systems to provide thermal comfort, which intensively consumes electricity and energy. Energy consumption has a major contribution to air pollution because it produces carbon emissions that directly influences quality of the air and human health. The percentage of Egypt's carbon dioxide emissions growth is about 170%. It has increased from 11.7 million metric tons in 1980 to 31.6 million tons in 1998. Egypt Country Analysis Brief 2004 explained that in 2001, the amount of Egypt's carbon dioxide emissions production is 34.3 million metric tons. At the same time, 0.52% of world carbon emissions is mainly a result of energy consumption, [4]. U.S. Department of Energy Office of Fossil Energy 2003 defined that world emission levels have reached 21% since 1990, [5].

To meet the minimum requirements of residential development in Port-Fouad, thermal comfort

has to be intensively considered without using mechanical ventilation systems and energy consumption reduction has to be accelerated. This could be achieved by enhancing building technology system within the new development of residential areas. Building technology defines the most appropriate planning and design criteria in relation to the environment that may increase air movements within the residential area and buildings. Results indicated that satisfaction could be achieved, particularly during summer time, by using methods of building technology such as passive cooling and natural ventilation systems. These methods facilitate initiating planning and design principles and elements that eliminate the use of electrical and mechanical systems in residential areas and, in turn, accelerate thermal comfort and environmental quality.
Therefore, the purpose of the research is to provide guidelines and criteria for planning and design for thermal comfort in residential areas, Port-Fouad Town. The capabilities of building technology, within this context, could be useful tools for increasing thermal comfort. Building technology system is capable for eliminating the use of electrical and mechanical systems in buildings and, in turn, accelerating thermal comfort and environmental quality. This hypothesis could be proved through the following: 1) analyzing building technology, in terms of its methods and capabilities; 2) investigating impacts of building technology on increasing thermal comfort and decreasing environmental impacts in different environmental conditions; 3) assessing an existing residential area, as a case study, that could provide significant satisfactory example for environmental safeguard of Port-Fouad. The assessment includes analyzing the existing residential area, in terms of its location, nature of climate, urban pattern and architectural elements; and conducting field analysis such as field measurements and questionnaires. The research concentrates on passive cooling and natural ventilation methods, especially airflow to reduce effect of high humidity and shading devices to reduce solar radiation, according to the climate conditions of Port-Fouad; and 4) recommending guidelines and criteria for planning and design concepts and details that could be adopted in residential areas in Port-Fouad.

3. KEY WORDS

Thermal comfort, building technology, passive cooling and heating, natural ventilation, macroclimate, microclimate, bioclimate, Port-Said and Port-Fouad.

4. BACKGROUND

Man always strive to create thermally comfortable living environments. These efforts has reflected on the development of communities since the dawn of the civilization. On the other hand, the American Society of Heating, Refrigerating and Air-Conditioning Engineers announced in 1998 that about 40% of energy consumption has been consumed in building heating, cooling and illumination. Meanwhile, Egypt stands out among middle-income developing countries as a very heavy energy user. The rate growth of buildings energy consumption has increased dramatically since 1974, even more than the rate of national income. The reduction of cooling loads for air conditioning, in addition, has become a critical concern because: electrical power is highly inefficient in its generation and related wastes are of large amounts; and the demand for air conditioning can be simply achieved by increasing the thermal performance of the building envelope and thermal design. One half of this energy consumption could be saved through applying proper building technology, [6,7]. Therefore, creating thermally comfortable living environments still one of the most important required parameters of planning and designing communities. This depends mainly on environmental, social and culture aspects of location; and building technology methods, which based mainly on decreasing the energy consumption and, in turn, environmental impact. Building technology provides methods and techniques of passive design systems. The advantages of building technology are enhancing better comfort and efficient energy consumption in buildings. The following parts investigate and analyze theoretical background of thermal comfort and building technology.

4.1. Thermal Comfort

Thermal comfort defined as: condition of mind which expresses satisfaction with the thermal environment; and as a condition of both physical and mental well-being. Providing internal climatic environment will not place undue stress upon the body's heat-compensation mechanism [8,9]. Therefore, thermal comfort has a great impact on living satisfaction and work efficiency.

The factors and variables influence thermal comfort are: 4.1.1. dynamic equilibrium with thermal environment, individual factors, thermal neutrality, local thermal discomfort, body heat exchange, the body's heat production, comfort zone, thermal indices and thermal loads in buildings; 4.1.2. macroclimatic variables such as macroclimate elements, regional effects on climatic elements, regional effects on urban vocabulary; and microclimate variables such as topography, ground surface, and three dimensions objects. The definition and explanation of the factors and variables could be summarized as of the following.

4.1.1. Dynamic equilibrium with thermal environment explains human effective temperature regulatory system, which ensures that body's core temperature is kept at approximately 37°C. The first comfort condition is thermal neutrality, which means that a person feels neither too warm nor too cold. Individual factors are concerned with human behavior. Behavior plays an important role in thermal interaction with the environment, which is a very active interaction between man and the environment. Thermal interactions take a number of forms; psychological, physical activity and clothing insulation. Time also plays a part in this interaction, [10].

Thermal neutrality defines the control system which regulates body temperature as a complex system. Sensors for control system are located in skin and in hypothalamus. The hypothalamus-sensor, located in the brain, is a heat sensor which starts body's cooling function when body's core temperature exceeds 37°C. Skin-sensors are cold sensors which start the body's defense against cooling down. When skin temperature falls below 34°C or raised above 37°C may cause death, [8].

Local thermal discomfort provides factors of discomfort which are related to internal environmental specification, internal ambience-color/reflectance, external awareness-size, color and type of glazing, pollutants created internally, level of boredom with work tasks, lack of local environmental control, lack of fresh air or much air movement, unacceptable temperature and humidity and lighting problems, [11].

Body heat exchange maintains body temperature at steady level, around 37 ^{o}C, by dissipating all surplus, particularly heat which must be dissipated to the environment. If there is heat gain from the environment that also must be dissipated. Body can release heat to its environment by convection, radiation and evaporation, and to a lesser extent by conduction.

The body's heat production explains sources and process of heat. All energy and material requirements of body are supplied from the consumption and digestion of food. The processes involved in converting foodstuff into living matter and useful form of energy as metabolism, only about 20 % of the energy is utilized. Remaining 80% is surplus heat and must be dissipated to the environment, [12].

Body is in thermal comfort when its heat generation rate equals its heat loss rate for normal body temperature. This implies that, as a whole balance, body must lose heat all time (at the appropriate rate) to feel comfort. Several factors must be considered as other climatic elements (relative humidity, air movement, solar radiation) and individual factors (Met rate and Clo value) which related to core body temperature and thermal balance, [13].

The comfort zones provide acceptable thermal environment for occupants wearing typical indoor clothing and at a near sedentary activity. Acceptable thermal environment is an environment which at least 80% of the occupants would find thermally acceptable, [14].

The physical environment consists of many elements in a complex relationship. One can try to describe the environmental constituents as: light, sound, climate, space, and animate. They all act directly upon human body, which can either absorb them or try to counteract their effects. Physical and psychological reactions result from this struggle for biological equilibrium. Man strive for the point at which minimum expenditure of energy is needed to adjust himself to his environment. Conditions under which he succeeds in doing so can be defined as the comfort zone, wherein most of this energy is freed for productivity [15].

Thermal indices are graphical diagrams and tables that express comfort zone. There are many indices. The most important indices are Effective temperature, Psychrometric and Bioclimatic charts, and Mahoney tables [16]. Mahoney Tables are based on a series of tables that had been devised by Mahoney. Although the tables had been developed for composite climates, they could be used for diagnosing any climate. These tables used for diagnosing the climate of Egypt according its meteorological stations.

Thermal loads in building explains conditions within a building, which could be determined by number of people, type of activity (metabolic), water vapor generated from kitchens and laundries, and home appliances use such as furnaces, ovens and computer terminals. Heat loss and gain, and thermal loads in buildings should be acquainted to construct an adequate design for thermal comfort. The total thermal load is the sum of external envelop loads, ventilation load and internal gains.

4.1.2. Macroclimate variables are a consequence of belonging climate conditions to a certain latitude and region. The climate of a place depends on its geographical location, latitude and longitude [17]. The macroclimatic elements are humidity, temperature, air movement, precipitation, cloud cover, sunshine duration, solar radiation and common climatic elements for building design;

Microclimatic variables represents local climate. Thermal performance depends on building design as well as on local climate that influences wind, humidity and solar radiation. Designing a climatic building conceders regional climate conditions then local climate conditions of actual location influenced by site factors, [12,13]. Every city, town or village may have its own climate, which slightly differs than its regional climate. The best procedure for designing a climatic building is to start with regional data and assess the likely deviations.

The interaction of solar radiation with the atmosphere and gravitation forces, together with the distribution of land and sea masses, produce an almost infinite variety of climates, boundaries of climatic zones that cannot be accurately mapped. One zone merges gradually and almost imperceptibly into the next. The classification of the climate based on the two atmospheric factors which influence human comfort: air temperature and humidity. The result is four climate zones: cold climates, temperate climates, hot-dry (arid) climates and warm-humid climates [12].

Urban vocabulary is an interwoven synthesis of many factors such as urban fabric, building shapes, orientation, and forms. Its organism reflects political and social tendencies as much as materialistic and technical requirements. Forming all of those factors, which are merged together into a composite picture, sometimes it seems difficult to analyze climatic environment as a separate element.

Urban fabric varies according to friendly or adverse climatic conditions. In cool climate, layouts try to provide shelter against winds. Large building units are closely grouped, but spaced to utilize beneficial sun-heat effects. Houses tend to join in order to have less surfaces exposed to heat loss. Town structure is an insulated dense layout. In temperate climate, layouts are open, nature and houses merge. Town structure utilizes possibilities of free arrangement. In hot-arid climate, layout is like a horizontal egg-grate device for shading. Dwelling units are arranged around closed courtyards and grouped together to achieve defense in volume. Town layout is shaded dense structure. In hot-humid climate, buildings are freely elongated, houses are separated to utilize air movements and shade of trees become an important element. The town layout is scattered and loose, [15].

Building shapes also influenced by regional climate conditions. In cold climate, dwelling units, with lack of heat, should be compact and double-shell structure to reduce surface exposure. Buildings should be protected from cold and high-velocity of winds. In temperate climate, dwelling units, with seasonal variation between under and overheating, must be freely organized and spread out. Cross ventilation and shielding are necessary, for summer and winter. In hot-arid climate, dwelling units, with overheating, dry air and large day/night temperature variation; should be constructed with small windows and massive adobe roofs and walls that have good isolating value and capacity to delay heat impacts for many hours. In warm-humid climates, dwelling units, with lower overheating than in hot-dry one, should be constructed and grouped in a way that allow free air movement. Cross ventilation is more important in warm humid climate than in any other zones, [15, 18].

Built forms require physical treatment to be adopted thermally with regional climatic effects. The elements of built forms are transitional spaces, solar gain, atrium, floor as exterior space (roof/ground) and primary mass. Transitional spaces, lobbies, stairs, circulation, balconies and any other areas where movement take place; do not require total climatic control and natural ventilation is sufficient. Transitional spaces should be located on the north and south sides in tropical and arid zones; and on the south side in temperate and cool zones. The location of solar heat gain spaces follows the varying sun-path in each climatic zones: in the tropical and arid zones at east and west sides; and in the temperate and cool zones at south side. Atrium should be located where it provides ventilation within the built form in the tropical zone; at the center of a building for cooling and shading purposes in the arid zone; and at the center of a building for heat and light in cool and temperate zones. The distance of the angled line from vertical represents the potential of each zone's roof and ground plans to be used as exterior spaces. In tropical and arid climates there is a high potential to make use of all external spaces, by moving towards northern latitudes. External spaces have to be covered to be used. The arrangement of primary mass, vertical cores and structure, can be used as a factor in climatic design as its position can help to shade or retain heat within a building form. Cores should be located on east and west sides to shade a building from low angles of the sun during major part of a day in tropical zone; on the east and west sides, but with major shading only needed during the summer in arid zone; on the north to leave the south available for solar heat gain during the winter in temperate zone; and on the center of a building to avoid blocking the sun's rays and to retain heat within a building in cool zone, [18].

4.2. Building Technology

The purpose of environmental controls is to ensure the best possible indoor thermal conditions by relying on structural (passive) controls, which may eliminate the need for any mechanical (active) controls, but even if mechanical controls do have to be resorted to, their task will thereby be reduced to minimum, [12]. The mechanical control should be used at necessary conditions at last step just after analyzing microclimate and structure controls to reduce the varying climatic factors.

There are many levels for climatic control (microclimate, structure and mechanical control systems). This research intended only to use building technology with relation with passive design controls which is the first known method for achieving thermal comfort, and best illustrated in ancient vernacular buildings, as a direct expression of adaptation to climate and resource constraints. In the 20th century man started to think of comfort as a product of energy consumption whereas building components, walls, windows, shutters, courtyards were used effectively as means of achieving comfort, [19]. Building technology which rely on passive controls for cooling and heating, may decrease the need for any mechanical controls. Building technology methods are; natural ventilation, shading control and passive capture systems

In building technology, planning and design are made to achieve bioclimatic comfortable indoor spaces with the least use of energy. The emphasis is on the design of building shell, every component of building is used to achieve comfort. The passive cooling, the shading systems, and thermal capture become very important systems of climate balanced design. Minimizing energy consumption could be achieved by interacting of designs and systems with surrounding environment, natural cooling and heating of buildings. The potential here has always been providing adequate comfort measures for occupants of the space, as well as reducing energy consumption. Therefore, design concept and detailing of building technology can provide significant support during planning and design process through adapting the following methods:

1.Basic technologies, resulted from passive design systems: includes three main sub-categories: Passive cooling systems, Shading control systems and Passive solar capture:

- Passive cooling systems consist of two methods:
    * Natural ventilation systems: are directly related to thermal comfort by increasing air velocity and increase air movement in warm humid climate. It is a primary method for cooling buildings and air renovation.
    * Evaporation cooling systems: decrease risks of dehydration.
- Shading control systems: decreases sunlight penetration into buildings.
- Passive solar capture: cools and heats buildings through selecting construction materials with appropriate characteristics suitable for different location environmental conditions.

2. Heat transfer in walls and windows by using suitable building materials for thermal storage and compatible technologies for heating and cooling.

5. CASE STUDY, PORT-FOUAD

The analysis of the case study is divided into four parts as follows: 5.1. selection of residential area, 5.2. description of selected residential area, 5.3. investigating urban vocabulary of the residential area, 5.4. analyzing a single ancient villa, which subdivided into four items: 5.4.1. building technology elements of the villa; 5.4.2. field measurements in winter and summer; 5.4.3. comparison between different villas; 5.4.4. questionnaire for all villas of selected lay out.

5.1. Selection of residential area in Port-Fouad

To define the suitable residential area, in Port-Fouad, for the requirements of analysis and assessment as a case of the research, different types of residential areas were compared, in terms of characteristics of urban vocabulary. Urban vocabulary provide essential basis for achieving building technology and, in turn, thermal comfort. The urban vocabulary are architectural style, shading devices, shading of plants, shading of last roof, shading devices by movable awnings systems, building heights, air movement between buildings, greeneries, building shape, external architectural details and pattern of urban fabric. The residential areas, accordingly, were divided into four zones. These classified zones are: Zone A: ancient villas of the Suez Canal Authority, 1920-1926; Zone B: residential buildings of individual families, 1960; Zone C: new residential buildings of the Suez Canal Authority, 1975; and Zone D: newly developed residential buildings by different co-operation groups, since 1980, Figure 5. As a result, residential buildings of Zone A were selected for research analysis because its urban vocabulary basis are quite enough for supporting the purpose of the research analysis. The urban vocabulary of Zone A include: suitable urban fabric for microclimatic of the area; unique style and building shapes; valuable architectural elements (shade devices, bitched roof, chimneys, etc.) compared to other zones; applicability of its elements in other new residential areas in Port-Fouad; etc.

As mentioned above, climatic zone of this residential area is warm humid zone, which characterized by high humidity of 14 %. Dr. Samir Hosni in 1980 used Mahoney tables to classify bioclimatic needs for cities and towns in Egypt, which indicates that during certain months natural ventilation, shading, thermal capture and other building technology are required. According to his results it is notable that the main problem in Port-Said could be solved by using natural ventilation systems for 7-8 months; time lag 3 hours for roofs with well isolation light materials; openings size of 25-40% of elevation area; and small wall thickness of concrete or sandwich panels with reflective outside material, [20, 21].

5.2. Description of selected residential area

The selected residential area consists of private houses (villas), which established in Port-Fouad in 1920-1926 as residence for employees, different ranked positions, of the Suez Canal Authority. They were grouped in separate and/or attached buildings, Figure 6 .The early occupants of these residential units were Italian, Greek and/or Armenian, Figure 7. In the 1970s and with the expansion requirements, the Suez Canal Authority built additional residential units. This development was in blocks of houses. Although there is no certain reservation policy for the heritage villas, the Suez Canal Authority has been maintaining these villas since their establishment. This maintenance of villas includes facades, internal finishing, plumbing, electricity, etc, [2].

5.3. Investigating urban vocabulary of the selected residential area

The general pattern of the residential area is radial with different sizes of blocks. On the edges of these blocks, the villas were rowed together in a leaner pattern and separated by different space sizes. Most of the streets are wide with curbs and greenery in the middle. The urban area consists of 10 double villas, 2-attached to each other, rowed on the edge of the block with green area in the middle. The purpose of this pattern of urban fabric is to utilize the air movement. Small percent of the elevations units are perpendicular to the prevailing wind, Figure 6.

Housing types are mainly private villas of 2-3 floors in height (7-10 meters) and private garden for all ranked personal of the authority. The high ranked personal occupy separate villa. The workers live in 2-attached villa. The building shapes are mainly of pitched roof with wooden skeleton and clay brick cover. There are wooden balconies on the different facades. The size of the openings is quite large comparing to newly developed residential buildings. Each villa or 2-attached villa is surrounded with a brick and wooden fence, Figure 7 .

5. 4. Analyzing an ancient villa

To achieve the objectives of the research, an ancient private villa was selected as a case study. The purpose is conducting different types of analysis such as measurements of air movement, temperature, humidity, etc. over a year and a questionnaire for villa's occupants. Figure 8 defines the location of the villa as No 1.

The villa consists of two stories, single side attached to another villa, with private back and front yards, and occupied by a single family. The ground floor includes a living room, an entrance lobby with staircase, a kitchen and a toilet. The first floor encompasses a lobby with a staircase, two bedrooms, a bathroom and a balcony. The structure system is wall bearing of massive thickness cement brick. The construction and finishing materials could be described as follows. Roof is made of pitched wooden with roof space (attic) for ventilation. Upper surface of the roof is covered with red clay tiles. Internal ceiling is flat and made of spruce wood. The external finishing material is exposed cement brick. The internal finishing material is light acrylic paint for interior wall. The internal floors are made of white marble for ground floor and spruce wood for upper floor. The openings are narrow tall and shaded with clear single glassing and wood sash (85% gross area equals net glass area).

5.4.1. Building technology methods and elements of the villa

The task of environmental controls is to ensure the best possible indoor thermal conditions by relying on passive controls for cooling and heating, which may decrease the need for any mechanical controls. This means that design and structure of buildings should utilize natural systems to improve thermal conditions and to avoid using any mechanical equipment.

Therefore, the research concentrates mainly on ventilation and shading technologies to cool the villa building naturally. As a result, building materials are of a little importance in thermal comfort for villa design because the range of night-to-day temperature is small (6.8 degrees). Materials with heat-storage capacity such as cement bricks with massive wall thickness (27-45 cm), in addition, are also of little benefit for thermal comfort particularly in bedrooms.

Sophisticated architectural details and openings were developed in the villa to achieve natural ventilation. This includes: openings for cross ventilation are almost opposite to each other through the villa to allow cross ventilation, particularly when doors opened in interior spaces; clear height of internal spaces is about 3.4 meter to allow fresh air flow. This height also increases the feeling of comfort and safety with the use of ceiling fans; the roof was constructed with a double roof system (attic), which reduces heat transfer. In summer, moreover, the attic can be ventilated by openings made in the upper corners of the walls (roof vents), and at the bottom (ceiling vent). As a result hot internal air could be exchanged. This technique maintains internal ceiling cold, in turn, reduces radiant heat to occupants; There are two vertical chimneys, in kitchen and bathrooms, with opening at the top to reinforce natural air convection by using solar heat system, Figures from 9 to 14.

The building heat gain had been minimized by shading the walls and windows by using different shading devices such as roof overhangs (fixed overhangs), balconies, trees, plants, pale colors for walls, wooden sashes, and recessing windows (deeper recession provide additional shade and control of glare), Figure 15.

5.4.2. Field Measurements

Field measurements also conducted in the selected villa over a year time. These measurements include air temperature, relative humidity, air velocity and air movements. Measurement time was selected according to climatologically data of Port-Said. Measurement time conducted in winter during January for lower air temperature and in summer during July and August for higher relative humidity and air temperature. Measurements instruments used were humidity measuring instrument (testo 615) and temperature/velocity measuring instrument (testo 435).

During winter time, the measurements have been conducted for five continued days starting on 4th January 2003, in villa No 1, in different conditions and spaces of the villa, with closed openings (glass/sashes), neglecting air flow, at the center of internal space and at 1.50 m height, Figure 17. The minimum comfort temperature in January was 20.1 °C. The results include: western spaces are the nearest to comfort temperature at night in January. The highest relative humidity percentages are in the internal part of the villa. Humidity is slightly higher in the rooms nearest the yards and higher in the ground floor than in the first floor. Bed room No. 1 is more comfortable at night than bed room No. 2. Bed room No. 2 is more comfortable during daytime than bed room No. 1. Generally, the internal air temperature has no effect on the occupants regarding thermal comfort during winter time.

During summer time, measurements have been conducted on 15 July 2003 all day long in villa No.

1 for four times; in villas No. 2, 4 and 5 for three times to determine the effect of internal partitions; and in villas No. 1, 3, 5, and 6 to determine the effect of different orientations, Figure 16. Measurements have conducted in each villa in main internal spaces, middle of space and at 1.50 high. Design of villas differs from each other. Villa No. 1, case study of the research, has no partition between the dining and living spaces at the ground floor, while partitions do exist in the same spaces of the other villas (2, 4). The findings include: maximum air velocities are at 6 pm. Ventilation at 1 pm reduces humidity but increase air temperature. Air velocities in upper floor is more than in ground floor. Effect of opening internal doors reduce the difference between recorded data. Air velocities in the western spaces are more than in the eastern. Western spaces store more radiation all day long than in the other spaces.

Thermal comfort is directly related to natural ventilation by increasing air velocity. The comfort zone relates to a higher temperature, which means that occupants fell more comfortable although the villa is not actually being cooled. Air velocities were used to evaluate thermal comfort inside the villa because air movement increases heat loss of human body and optimizes the human evaporate cooling process, Figures 18 and 19.

5.4.3. Comparison between different villas

Comparison between different villas and cases to define planning and design guidelines and criteria for increasing natural ventilation in residential areas in Port-Fouad, Figure 16. Two main comparison analysis have been conducted in summer time for the above mentioned villas. This analysis includes: comparison between different locations of the same villa type on the same block to indicate the effect of partitions and orientation.

The first field measurements compared between villas No. 1, 2, 4, and 5; have been conducted on 1st August, 2003 at 1–2 pm (peak hours). Villas No. 1 and 5 have partitions in the ground floor, while villas No. 2 and 4 do not have internal partitions between living and dining rooms. The results indicated that villa No. 2 has the highest value in the ground floor in living and dining rooms due to the absence of internal partition between living and dining rooms, Figure 20.

The second field measurements compared between villas No. 1, 3, 5, and 6; have been conducted on 3rd August, 2003 at 1–2 pm (peak hours). The findings indicated that villa No. 1 has the highest value in ground floor in living room due to its orientation to prevailing wind. The best orientation to prevailing wind for openings is northwest – southeast, Figure 21.

5.4.4. Questionnaire

A questionnaire has been conducted over a year long. The questionnaire were handed out to occupants of the selected villas on 15th July. The purpose of the questionnaire is evaluating villas thermal performance during summer and winter. The questionnaire sheet was in Arabic language, with direct and simple question because the occupants are mainly workers of the Suez Canal Authority. The results are classified according to time, summer and winter, which could be concluded as follows (percentage indicates the agreed occupants of the total responded occupants to questionnaire).

5.4.4.1. During summer time:

- For ventilation:
    * Feeling of higher air temperature and humidity percentage in the ground floor 100 %.
    * Preferring Higher ceiling 80%.
    * Using fans: importance of daily use 100 %; up to 4 hours use 90 %; at night use 100 %; and in ground floor use 100 %.
    * Inability to accept humidity with closed openings 100%.
    * Unacceptable pattern of outer openings: high and narrow 85 %.
    * Importance of keeping internal doors opened between spaces 60 %.
    * Importance of keeping external doors opened most of the day 70 %.
    * Excluding property boundary fences and terraces to increase air flow 80 %. The rest (20%) reject that choice for privacy purposes.
    * Accepting current natural ventilation inside the villa 70 %.
- For shading

* Importance of using internal wooden sashes for privacy factor 70 %.
* Importance of using air conditions 10 %.

5.4.4.2. During winter time

* Sun penetration inside internal spaces 50 %.
* Preferring bitched roof for rain protection 85 %.
* Making ground floor more thermally comfortable 50 %.
* Humidity has direct negative impact on internal paint 100 %.

- For internal finishing
    * Preferring wooden floors in upper floor 80 %.
    * Preferring wooden floors in winter80 %.
    * Preferring oil paints for internal walls 70 %.

6. Guidelines and Criteria for Thermal Comfort in Residential Areas in Port-Fouad

In the study region, Port-Fouad, the minimum external temperature in winter is10.7 °C, the maximum external temperature in summer is 31.6 °C, and the maximum external relative humidity in summer is 73 %, while human comfort range is limited between 22.1 and 26.1 °C for air temperature, and is 30 – 65 % for relative humidity. As a result, the main objective is to design a passive systems by using building technology, to decrease maximum summer temperature, and relative humidity through passive cooling and ventilation systems, and the less important principle is to increase minimum winter temperature. The main important building technologies to maintain thermal comfort in the case study as the main objective of the research are natural ventilation and shading control systems. The detailed planning and design guidelines and criteria for enhancing thermal comfort in residential areas in Port-Fouad are defined as a result of the research analysis and investigation; data collection, field measurements, comparison and questionnaire. The guidelines and criteria are divided into two main categories: General and specific, as of the following.

6.1. General guidelines and criteria

- For designing a climatic building, the first concern is regional climate conditions, then local climate conditions of actual location.
- The internal thermal gain from solar radiation is smallest in rooms with northern orientation and largest in room with western orientation. Western orientation is less thermally comfortable than other orientations especially at night in sleeping areas without natural ventilation.
- Night ventilation increase internal relative humidity and reduce internal temperature.
- At evening, western spaces have higher internal temperature than outside due heat stores in its external wall. By night natural ventilation these spaces can reach thermal comfort levels.
- At noon, the highest outside air temperature increases internal air temperature. Using natural ventilation increases thermal comfort due to increased air velocities inside the buildings. This means that the comfort zone shifts to a higher temperature and occupants of the building will feel more comfortable, even though the building is not actually being cooled.
- Opening location should be opposite to each other to allow cross-ventilation and, in turn, increase internal air velocities.
- Using opened internal spaces allow more air velocities than subdivided internal spaces.
- Internal doors between spaces increase natural ventilation in case of subdivided spaces, especially in rooms in the downward sides.
- Facilitating flexible pattern of external door has significant effect on increasing air flow inside buildings.
- Selecting openings with special pattern and mechanism highly affect natural ventilation, wider openings with fanlight are the most preferable.
- Providing higher internal clear heights facilitates using fans, especially during nighttime.
- Enhancing natural ventilation is preferable than using air condition to achieve thermal comfort.

- Humidity has harmful effects on paints all year long.
- Using solid fences reduces air velocities in adjacent spaces in ground floors.
- Incorporating roof overhangs reduces internal air temperature and contribute to cooling of buildings.
- Facilitating natural ventilation has important effect on achieving cooling sensation of occupants due to heat loss by convection and due to increased evaporation from human body.

6.2. Specific guidelines and criteria

- For ventilation

* Using long and narrow floor-plan in sleeping zone to maximize ventilation in bedrooms and elevate house to catch breezes.

* Designing open-plan living areas, to maximize air movement .

* Using high ceilings to allow heated air to rise out of occupied zones and to reduce radiant heat of occupants; and facilitate opening inlets and outlets within the same wall and using ceiling fans.

* Providing flexible patterns of doors and windows, especially external main door, such as upper openings to maximize air change and to allow hot air rises and replaced by cold air from lower vents, convection ventilation.

* Avoiding blocking airflow by boundary fences, lower cyclone-wire fence is preferable than a high brick wall.

* Locating openings opposite to each other to allow cross-ventilation.

- For shading

* Designing small window sizes on east and west walls with using shading devices.

* Using pale colors for walls and roof to reflect the heat of the sun

* Enhancing double roof system (attic), with internal ventilated space.

- For building materials

* Using light construction materials, with capability of cooling, particularly at night in bedrooms.

* Using materials with lowest time lag and thermal storage.

7. CONCLUSION

The study has discussed possible planning and design guidelines and criteria for enhancing thermal comfort in residential areas in Port-Fouad, Egypt. The background has illustrated the use of building technology system, particularly natural ventilation and shading control methods, for enhancing thermal comfort in residential buildings. The results obtained from the analysis of the existing ancient residential area and villas, as a case study, in Port-Fouad provide strong evidence that the capabilities of building technology systems could play a significant role in enhancing the thermal comfort in new development of residential areas in Port-Fouad. The urban vocabulary and architectural elements of the case study, as a major part of building technology, would be suitable for enhancing thermal comfort in residential buildings in port-Fouad. In other words, it could be concluded that thermal comfort could be enhanced in Port-Fouad by the use of sufficient natural ventilation methods, which could eliminate the need for any air conditions as possible. Consequently, building technology methods should be considered for enhancing thermal comfort in residential areas in Port-Fouad. In addition, it is not merely the enhancing of the thermal comfort, but also decreasing the energy consumption and its environmental impact. This is because energy consumption has a major contribution to air pollution because it produces carbon emissions that directly influences quality of the air and human health. The controversy of environmental impact of energy consumption arises as a result of rapid rate of growth of Egypt's carbon dioxide emissions, which is about 170%.

The results, moreover, focus on the capabilities of building technology, which could be applied to enhance thermal comfort in residential areas in Port-Fouad. The natural ventilation and shading control methods are not restricted to the location, size and kind of residential areas. It takes the macroclimate, microclimate, location, urban vocabulary, architectural elements, structure system and construction materials into account. It also considers the capability of construction material, and orientation, height, shape and size of buildings, greeneries, etc. to enhance thermal comfort.

The procedure developed will have a wide application to other residential areas in Port-Fouad and in other cities in Egypt. These application may include enhancing thermal comfort in newly developed and/or existing residential areas such as B, C and D in Port-Fouad. Thermal comfort could be enhanced in existing residential areas by renovating and adopting the recommended guidelines and criteria at all levels of development, from urban to fine architectural details.

The public and private sectors in Egypt, in fact, develop annually a massive amount of residential areas all over the country. The findings of this study could be directly applicable in the formulation of this urban development and legislation. It could guide the planning and design of new urban development in any city or town with respect to the environment. This systems and methods could also be an example for many other parts in the world to develop urban development with sustainable agendas.

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Fig. 1: Egypt, [22].

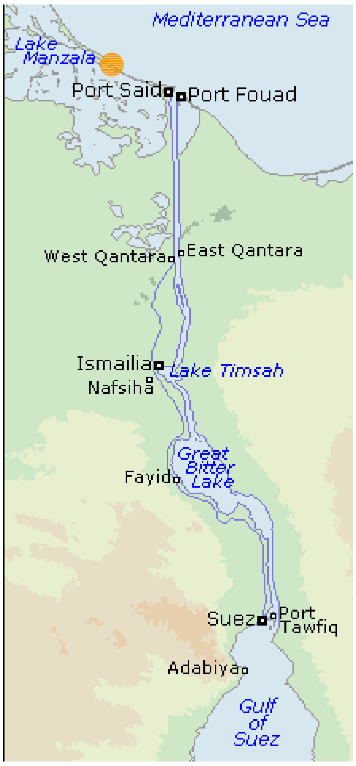

Fig. 2: Suez Canal Zone, [23].

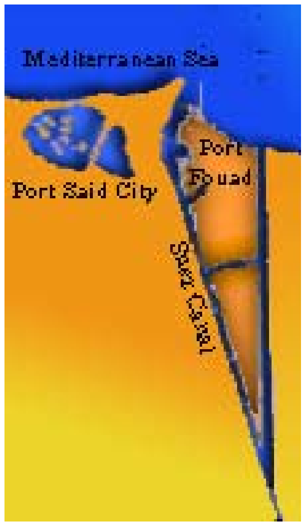

Fig. 3: Port-Said and Port Fouad, [2].

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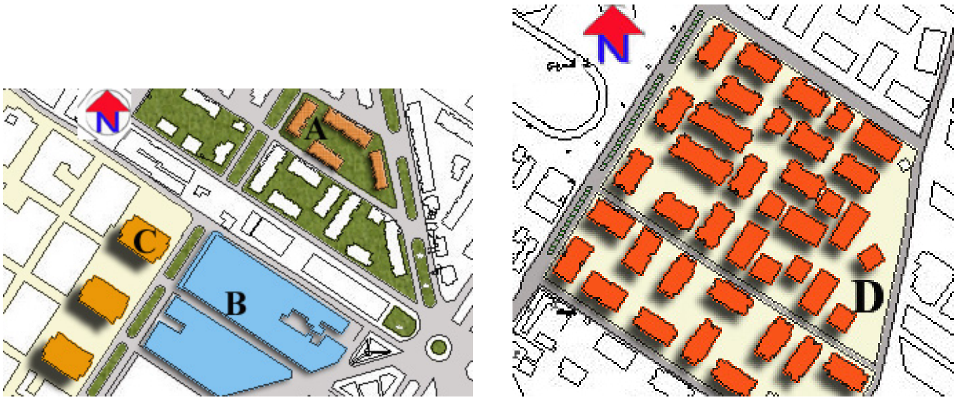
Europeans building style

Natives building style

Fig. 4. Main styles of buildings in Port-Fouad, [24].

Fig.5. Building shape for zones A ,B, C and D.



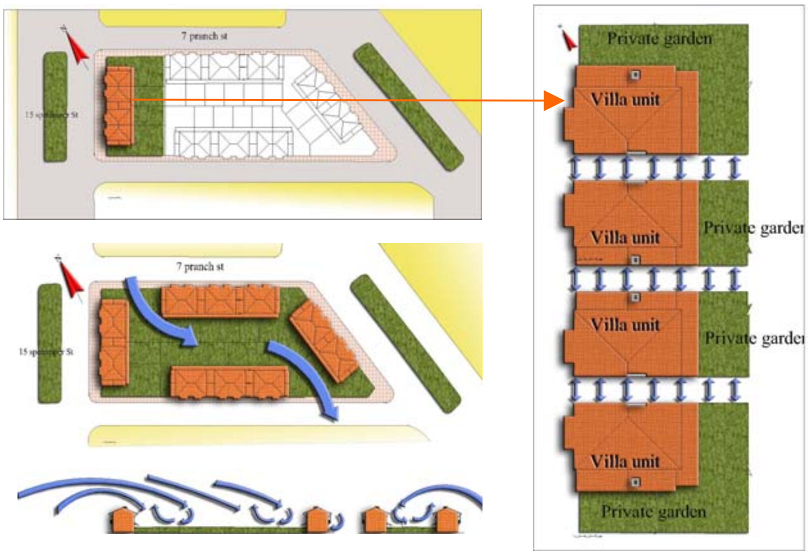


Fig. 6. Urban fabric of villas units and air movements .

Fig.e 7. Elevations (back- front) and layout of selected villas.

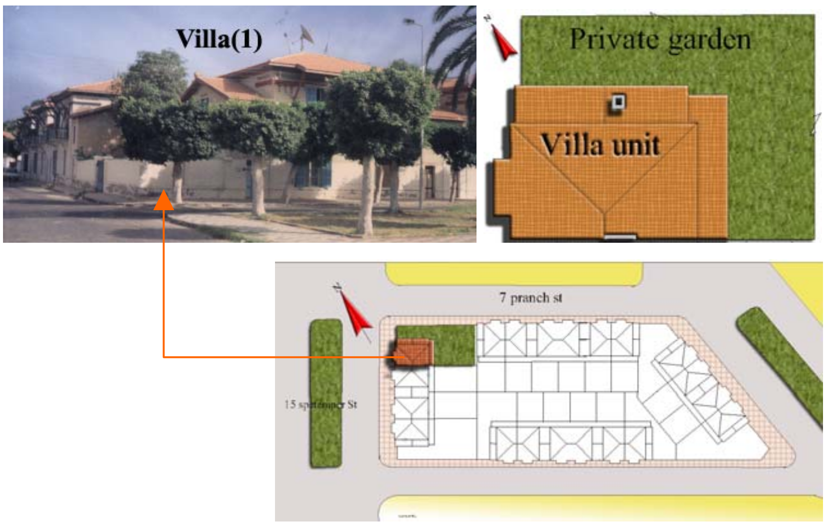


Fig. 8. Location, lay out and building shape. of selected villa (No 1).

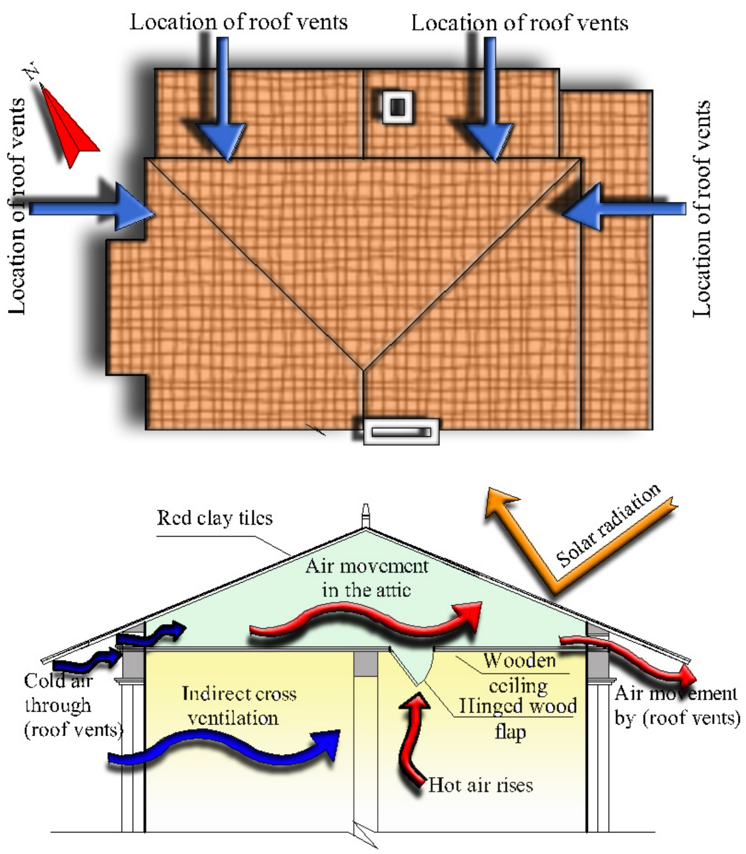
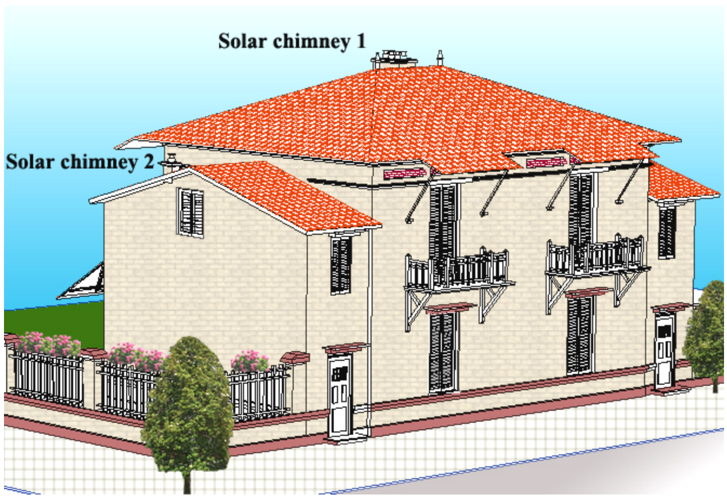


Fig. 9. Roof vents mechanism of the double roof construction for cooling the upper floor and preventing radiant heat.



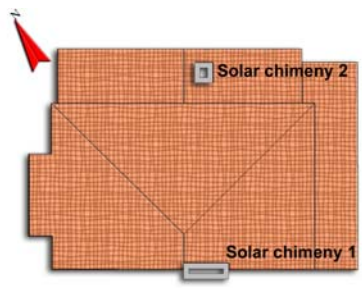


Fig. 10. Perspective and layout of the two chimneys.

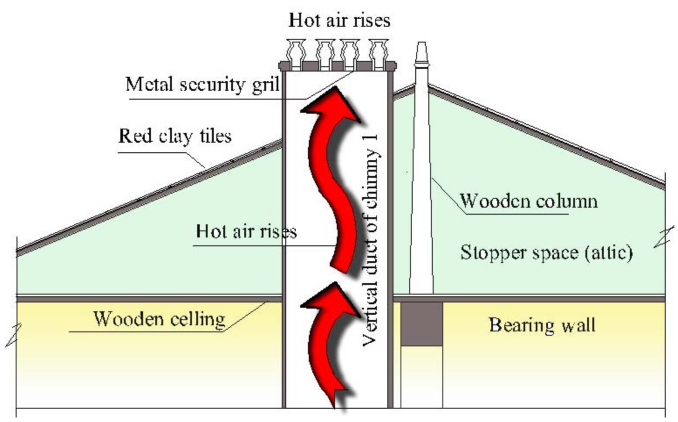


Fig. 11.Vertical duct of chimney1.

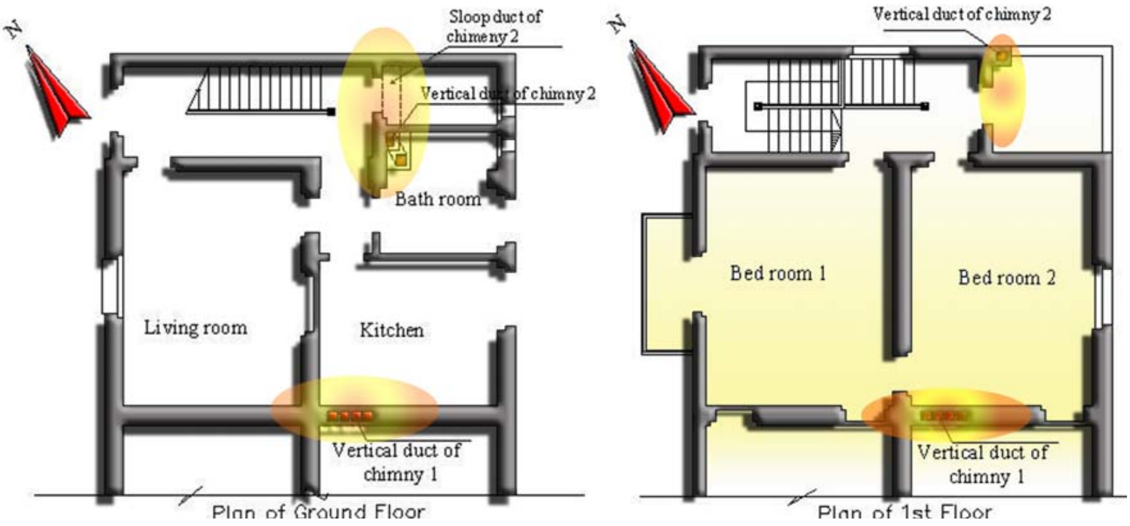
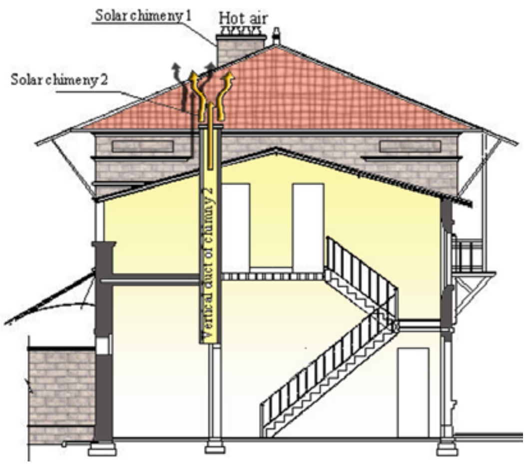


Fig.e 12. Plans of ground and 1st floors shows location of chimney1 and 2 .



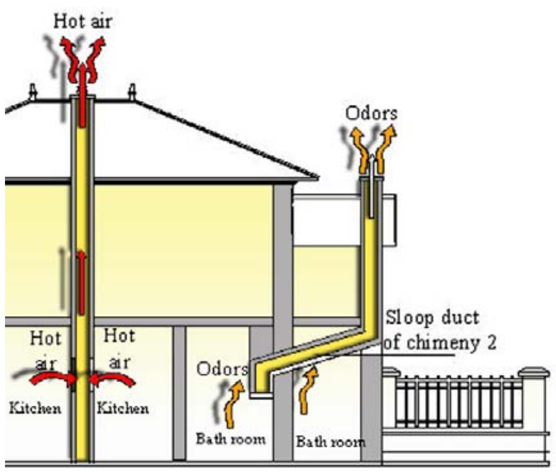


Fig. 13. Vertical duct of chimney 2.

Fig. 14 Vertical duct of chimney 1 and the common pathway for chimney 2.

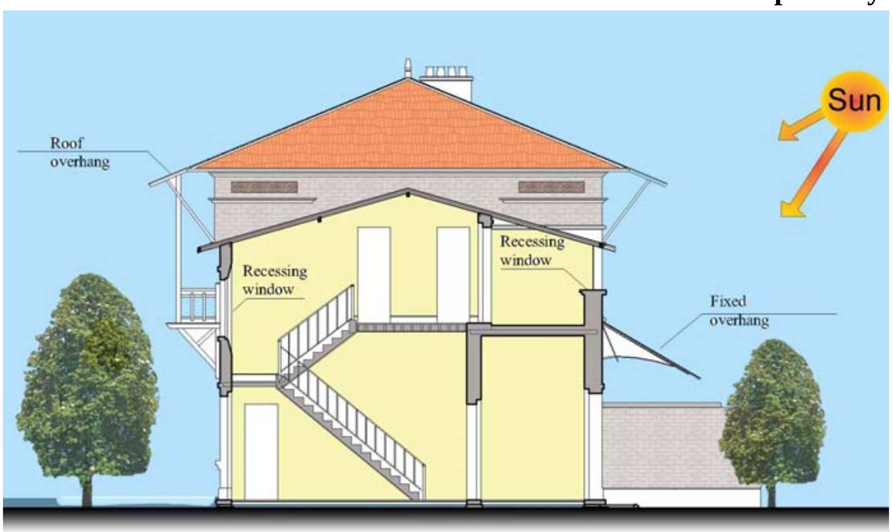


Figure 15: Section, layout, and perspective of selected villa showing nature of al shading system in the villa.

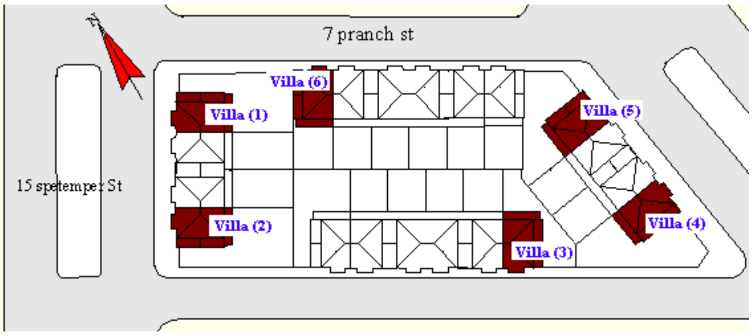


Fig. 16. Layout for different compared villas in selected layout.

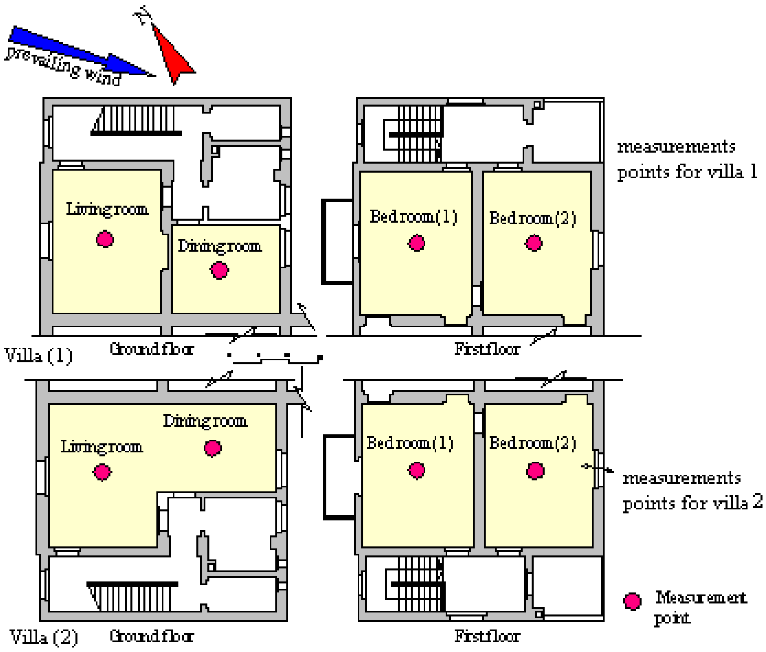


Fig. 17. Field measurement points at summertime.

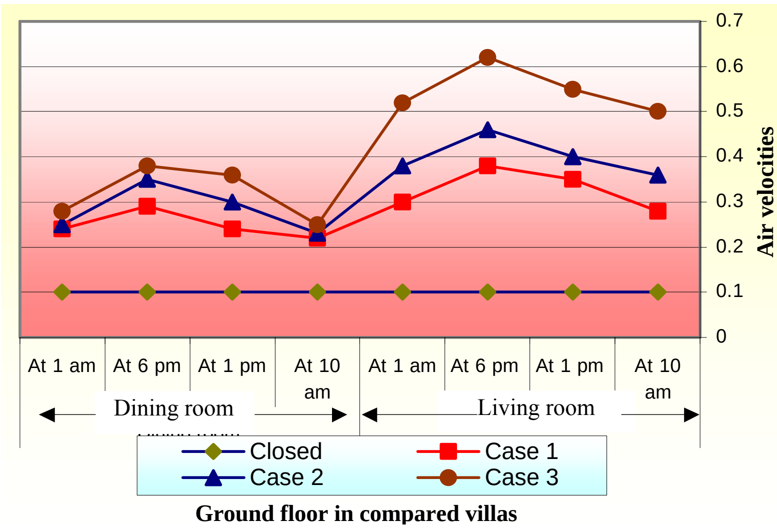


Fig. 18. Air velocities (m/s) at ground floor through the day.

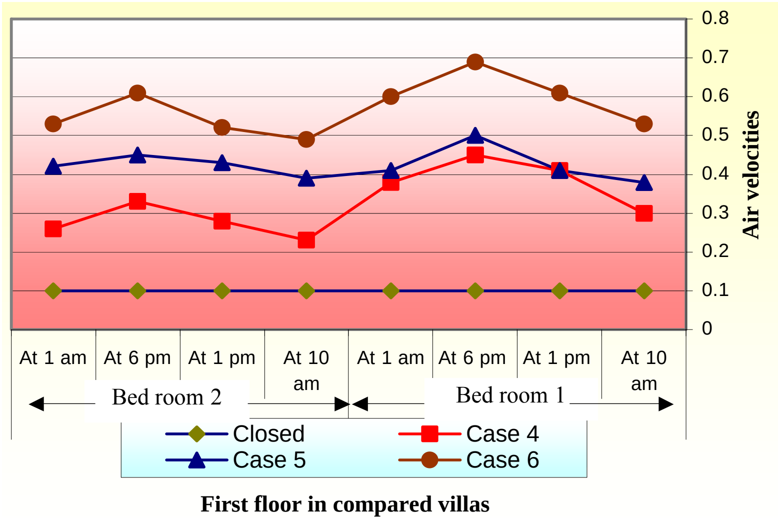


Fig. 19. Air velocities (m/s) at first floor through the day.

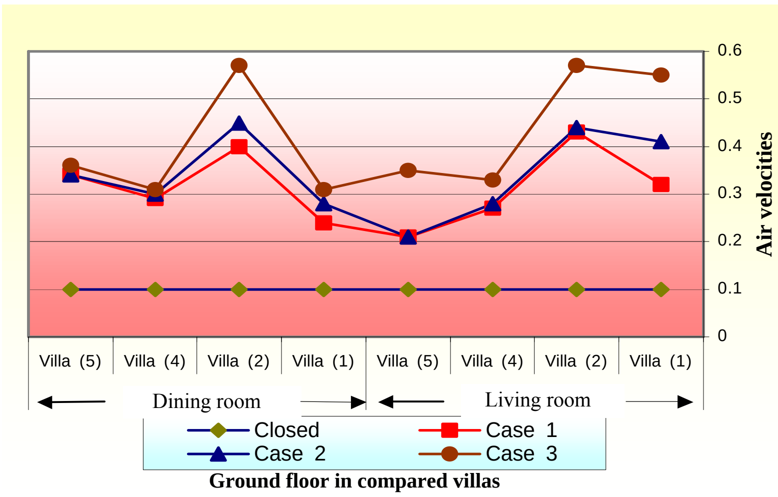


Fig. 20. Air velocities (m/s) at ground floor in compared villas at 1pm to indicate the effect of partitions.

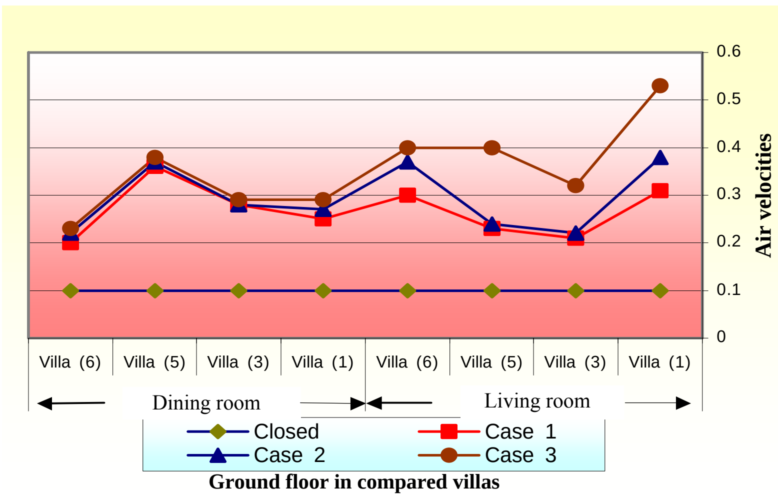


Fig. 21. Air velocities (m/s) at ground floor in compared villas at 1pm to indicate the effect of orientation.