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Mud-Brick High-Rise Buildings Architectural Linkages for Thermal Comfort in Hadhramout Valley, Yemen

Anwar Ahmed Baeissa [a*]

[a] *Department of Architecture & Environmental Planning, Faculty of Engineering & Petroleum, Hadhramout University of Science & Technology, YEMEN*

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ABSTRACT

The Hadhrami master builders have successfully played a great role in sustaining architectural identity of their cities with linkage to the local culture. They could build up to eight storey's high- rise mud buildings using local and traditional materials. Today, reestablishing this architectural identity is rather more challenging due to the modern, social, political and economical changes that created poor linkage to the present city's identity. This paper investigates this issue and searches for guidelines for the sustainable city's development in Hadhramout, Yemen. The paper analyses the qualitative values of the city planning and architectural linkage compared with the city's development and how the past generations created and sustained it. Shibam city with its traditional five to eight storey's buildings is one of the best examples for this study. All buildings in that city are linked from one to another through roads, doors and openings of the high rises facing these roads and passageways to form unique urban setting and to provide shades and ventilations to the roads and passages and reduces temperature in these areas. This study is important to guide us in the analysis to search for better definitions of the linkage.

1. Introduction

Planning and architectural linkages play a crucial role in providing the identity of the city settlement areas for the people who live in the city. Today, the city experiences a high growth economic development in Yemen. This can be seen in the urban development in most Yemeni

*Corresponding author (Anwar Ahmed Baeissa). Tel/Fax: +967734066823. E-mail address: dr.anwarbaesa@gmail.com. 2014. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies. Volume 5 No.3 ISSN 2228-9860 eISSN 1906-9642. Online available at http://tuengr.com/V05/0167.pdf.

cities due to the increasing population. The motivation of the government of Yemen to develop strategic master plan is manifested in the on-going governmental activities in the concerned areas. All geographical regions in Yemen (Figure1), including Shibam City, can be characterised by a diverse settlement of traditional houses from region to another due to the geographical variations, diversity of climate and topography which have influenced the use of the construction technique and materials. The city is the man's location in a specific geographical and social framework through which he expresses the ideologies he believes in and his opinions about the world. The city is the product of man's awareness, which he utilises to create civilisation and produces creative ideas to establish and develop cities in order to communicate with other civilisations. On the other hand, the city responds to man's social, political, and economical requirements bearing in mind that the city is the society's materialistic expression of beauty and local intellectual features that may be exhibited in its purposive special planning and organisation. Overtime, traditional housing and settlements have developed a unique design, planning, technology, and the use of available local construction materials for the traditional houses. This was possible by transferring the experience of one generation to another and applying trial and error method as well as developing the construction techniques.

Figure 1: Map of Yemen

2. Problem Statement

Community is a part of the decision makers in creating forms of settlement. The community has arranged spaces for their activities based on mutual agreement, in order to

accommodate these functions and its spatial termation on the arrangements. The Hadhrami is strongly bond to his land and city and at the same time, the city is bond to civilization that man produced. Some consider the city as the civilization itself. However, the man is the creator of civilisation and he establishes new elements and utilizes his creativity to contribute and to produce and develop the civilization's entire products in order to communicate with other civilisations. The old ancient Hadhrami realised the various functions of the housing units with thermal comfort and its relation to the outside neighbouring areas such as streets and public places; this in turn led to the fulfillment of the social integration, (Al-Shibany, 2000). The present private ordinary houses and public buildings (shops, mosques, offices, schools, etc) in the same vicinity enforce indirect security in the urban environment. Urban communication and development can generally be achieved when man succeeds in linking his past history and heritage to his present time. Based on the accumulation of architectural knowledge, the Hadhrami architects have sufficient experience, which qualifies them to deal with various circumstances of time, space and shape in functions of the spaces that suit Hadhramout environment, and architectural heritage. Today, high-rise buildings are deteriorating and the features of the cities are changing in Hadhramout valley, so this architectural identity is rather more challenging and difficult because this development is confronted by the modern, social, political and economic changes and challenges.

3. Study Methodology

The methodology of the case study derives from the paper objectives. The study methods adopted on analysis method and case study to explain the relation between qualitative values of the city planning and architectural linkages with comparison to the stages of the city's sustainable development. This methodology based on physical survey (which concerned with the layout of sample areas) and site observation (this measure adopted to record the physical conditions of the residential environment).

4. Shibam City and Houses

There is an ancient city in the middle of Wadi Hadhramout called Shibam (Figure 2), It is existence is virtually comparable to the ancient Babylonian and Sumerian cities. It is located approximately 600–700 meters/1900–2300 feet above sea level. Villages and cities located in the valley are surrounded by tress. A clay-brick for trees wall (*sur*) ranging between 5 and 9 meters and 29 feet in height; was built along its southern part that runs through Wadi Hadhramout, which separates it from the coast (*sahil*) of the city Shibam. During the 4th

*Corresponding author (Anwar Ahmed Baeissa). Tel/Fax: +967734066823. E-mail address: dr.anwarbaesa@gmail.com. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies. Volume 5 No.3 ISSN 2228-9860 eISSN 1906-9642. Online available at http://tuengr.com/V05/0167.pdf.

century BC the city of Shibam played a key role as the capital of Wadi Hadhramout. In addition, it is distinguished by being an important commercial center in the area during the pre-Islamic period, having the wall (*sur*) of the city, being commercial capital, and a assembly-point for the caravans of the tribes of the valley as well as the tribes from the north. Today Shibam City enlisted to UNESCO heritage lists, (Lewcock, 1986).

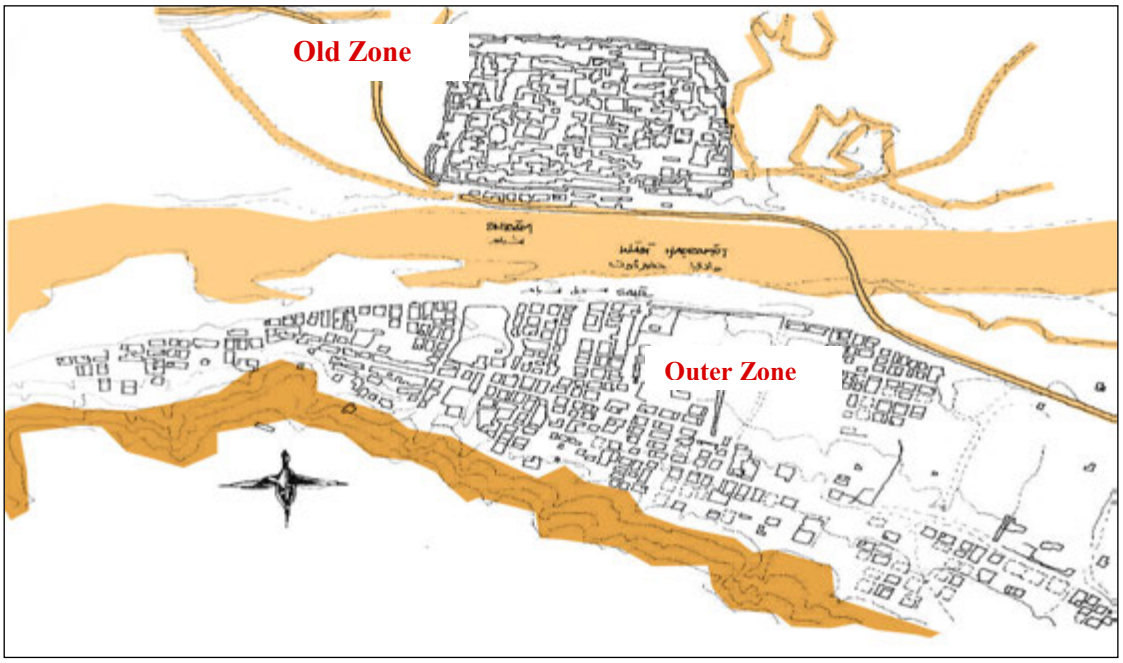

Figure 2: Map of Shibam City

The architectural design of Shibami houses, which reflects its heritage, has succeeded in achieving this communication through the vicinity of urban utilities, housing units, and public facilities, which provides more security and prevents any threat to the urban area and its neighbouring regions. However, old houses that may collapse are abolished and then the new buildings are to be reconstructed it in the same location as per the original design. Other construction activities in the city are limited to repair and maintenance works, and to some extent modifying the existing buildings. Therefore, it is difficult to date precisely any of the houses in the city.

4.1 Shibam City Plans and its Architecture

Among other features that make Shibam a unique city is that this city has huge concentrations of tall houses built upon the elevated mound that rises out in the valley floor; a fortified city wall around the city at its base surrounds the mound (Figure 3). There are many natural factors combined to mould the plan of Shibam into its present, mainly due to the nature of the ground on which it is built. Archaeological evidence has yet able to support the

argument that this city was built on top of the ruins of an ancient Shibam. This would explain why it rises above the ground level of the surrounding valley. Furthermore, according to historian (*Sabban*), the area of land which Shibam occupied in the past was larger than the land it occupies now, since part of this site was eroded by the torrential flood streams (*Suyul*), particularly in the years AD 1298/ AH 698 ,1532 / AH 939 and 1562 / 970. The dimensions of its present site are 355 meters (388 yards) to the south of the center, and 295 meters (322 yards) to the north, with 230 meters (250 yards) to west and east. The city lies along rocky maintain of the south, making it expand to that direction. Moreover, on its northern, western and eastern borders, the city is surrounded by palm trees and fields reserved for cultivation. Hence, we find that the horizontal expansion of the city consisted merely of the construction of a few building outside its southern walls, (Damluji, 1992).

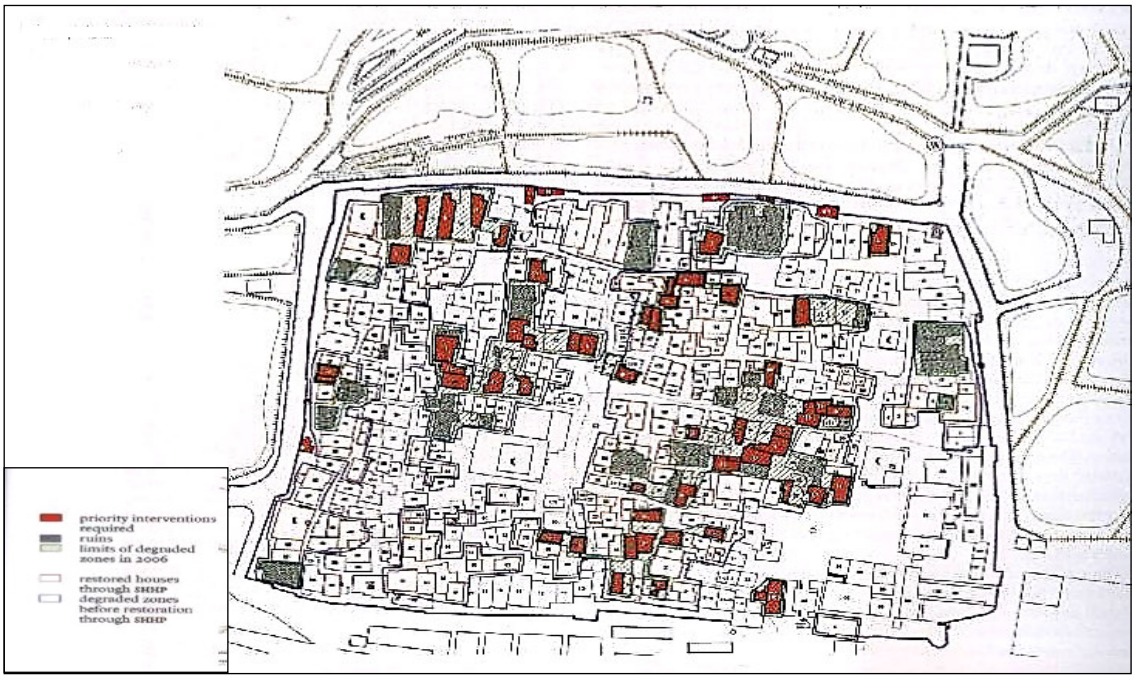

Figure 3: Map of Shibam City (Source: Aga Khan Award for Architecture, 2007)

Therefore, the citizens of Shibam had to resort to the construction of close-knit, narrow but high buildings, rising up to seven or eight storey's, with ceiling-heights ranging from 2 to 6 meters / 6.5 to 19.5 feet. The tallest house rises 29.15 m above its entrance on street level and 36.5 meters above the Wadi bed. It has nine floors, mean while many others have eight, or seven storey's if they are on low-lying ground, but the average number of storey's is normally five. The highest houses are mostly found in the edge of the mound. They are composed of more or less solid for trees walls facing east, south, west and north. The north and south sides are the longest. The city is surrounded by the date plantations at east, west,

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and north sides, whereas, the south side, lies on the Wadi bed.

The erection of several long houses on the Wadi bed outside the walls constructed during the last few years have marred the visual effect of the city. One of the proposals submitted to the plan of action of the international campaign for the safeguarding of Wadi Hadhramout is that the most recent buildings are to be demolished or reduced in height, to single-storeyed or at most double-storeyed buildings, so that will set off, rather than mar, the extreme height of the buildings within the town.

Across the Wadi lies the suburb city, which was earlier a garden suburb, but has become concentrated into an urban area in the last twenty years. It is not intended that this garden suburb should be included in the conservation area. Amongst other reasons for the unfeasibility of horizontal expansion are the political unrest. The city had been through that had a negative impact on architecture and planning. In addition, a hot climate has made the houses to be close-packed, and the streets are to be shaded to avoid the scorching heat of the sun. Shibam, like other cities in the Wadi, has a dry desert climate; extremely hot in summer and moderate in winter, with a sharp fall in the temperature at night. In addition, due to its closeness to the equator, heavy seasonal rain falls sometimes during the summer, sometimes causing floods which may last for days.

Figure 4: City of Shibam – View Expansion

4.2 The Effects of Population Growth and Architecture

The official census carried out in 1973 shows contradictory figures between the population of Shibam and the low land of Shibam (Figure 4). However, according to the unofficial census carried out by the local 'Popular Defence Committee in 1976', the population of Shibam was 3491 and the number of houses 500, ten of which required reconstruction. The plan of the city is concentrated along a high rocky mountain and along its surrounding wall. This means that the design has a limited, fixing number of buildings, which can be constructed, on its ground, and thus limiting the possibilities of change in its basic architectural structure over years. Thus, we find that the number of buildings in the city, still 500, the same as recorded in the last century by the early western travellers. It may have been the same ever since the city and its walls were the first to be constructed. According to a report by the still outdated Ministry of Local Rule, the population of Shibam was estimated at around 5000 in 1980, putting the number of inhabitants per personal. On the other hand, in this study on Shibam *Abdul Qadir al-Sabban* estimated the population at around 6000 people making the ratio of inhabitants to each houses around 12 persons.

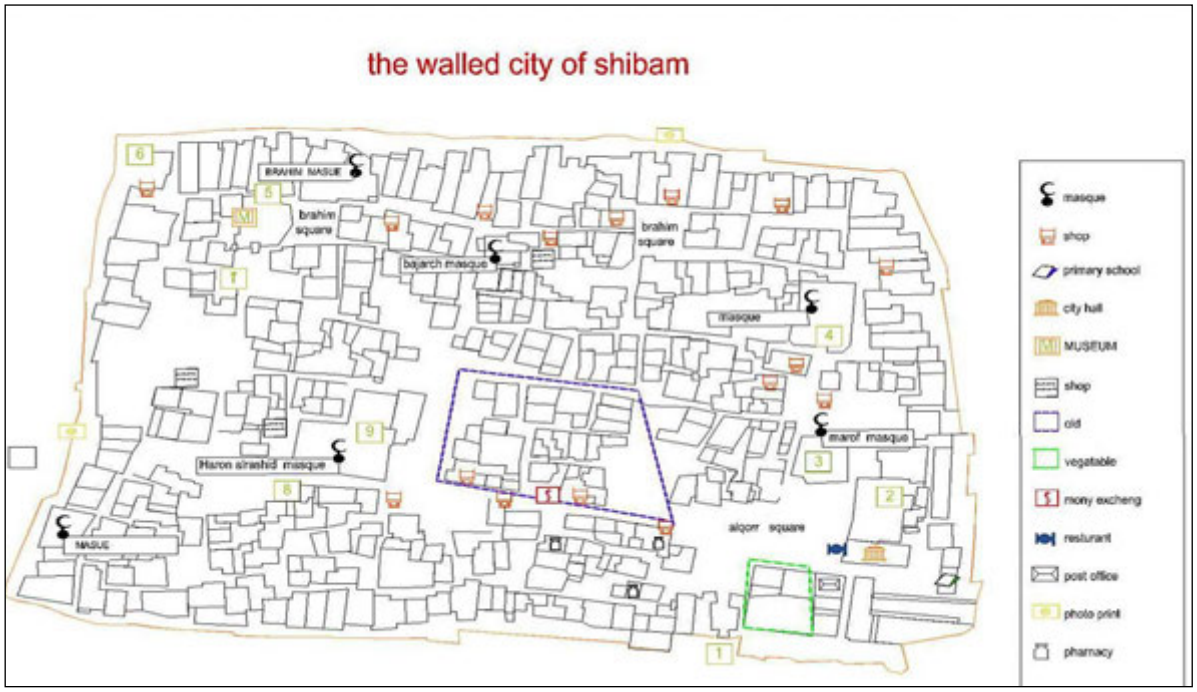

Figure 5: Map of Walled City of Shibam

4.3 The City Wall and Entrance (*Sur* and *Siddah*)

The old walled city of Shibam is located on an elevated land to the north of the main wadi bed, which is quite close to the point where a number of tributary wadis converge. Mud-

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brick wall (*sur*) surrounds the city (Figure 5). The height of the wall varies between 6 and 9 meters (19 to 30 feet). There exists only one main gate to the city. When closed during the night and wartime, it isolates the city from the outside world. It occupies a non-central position at a distance of a few meters from the main road of the valley on the southern edge of the city near to its eastern facade. The roads surrounding the southern and eastern sections of the city wall are separated from the public commercial centre of the city by the wall. It also separates the road from the fortress (*husn*) from the administrative centre of the city and the place of the Sultan. A few mud buildings have been constructed between the (*sur*) and its (*siddah*) and the main road. These buildings, which ones upon a time served as commercial and public places, are currently utilized to serve other purposes such as stores, cafes, inns, garages, etc.

The dimension and style of these buildings are different from those of the typical Shibam ones. They are either one or only a few storey's high. The *siddah* represents the main defensive position in Shibam. Its southern and northern facades are congruous. It is prominent from the rest of *sur*'s structure because of its dimensions and characterised by three arches: the main central arch and two smaller arches. The central arch contains a large wooden gate that is used at present by cars whereas it was used by caravans and camels in the past. The smaller arches are located one on each sides of the main arch, each having a gate smaller than the main and are used by the pedestrians.

Figure 6: Public Squares and City Wall of Shibam

4.4 The Public Squares (*Sahat*)

The plan of the city of Shibam with its narrow sheets with limited available land area incorporates five public squares (Figure 6). Closed packed houses with public buildings are located around these squares. The main square is called (*Sahat al Husn*) and covers an area of 39 x 79 meters (43 x 86 yards). *Sahat al-Rashid* Mosque is the second largest square with an

area of about 79 x 24 meters (87 x 26 yards). This mosque has been founded at the time of the Abbasid Caliph *Harun al-Rashid*, hence carries his name. The other three squares function as residential public squares are relatively concealed in the street plan. These squares are known as *Ma'ruf, Braham*, 27.3 x 21.3 meters (30 x 23.3 yards) and *Badhib*, 22.3 x 18.8 meters (24.4 x20.5 yards). These names are given after the names of the neighbouring mosques. High buildings surround these squares with open spaces that function as communal centers that attract visitors and the immunity on many social and commercial occasions. Moreover, there are small shops in the narrow streets and alleys forming the façades with commercial activities. These are known as (*al-dayqah*) that are characterised by narrow entrances on the ground floors of the houses next to their main entrances.

5. Traditional Layout and Climate in Shibam City

In designing and planning dry, wet and hot regions, architecture encounter two major problems:

1- Securing protection from heat,

2- Providing sufficient air conditioning.

The sun, a main source of light and heat, forms certain secondary element of climate such as winds and humid which have a significant effect on man's physiological wellbeing and comfort. Undoubtedly climate is a determining factor in Shibam traditional planning. Thus, it is noticed that there is a sort of systemization in the urban structure of all dry and hot regions; the traditional planning of the town is characterized by:

1 - Narrow zigzag roads,

2 - Vast open Squares.

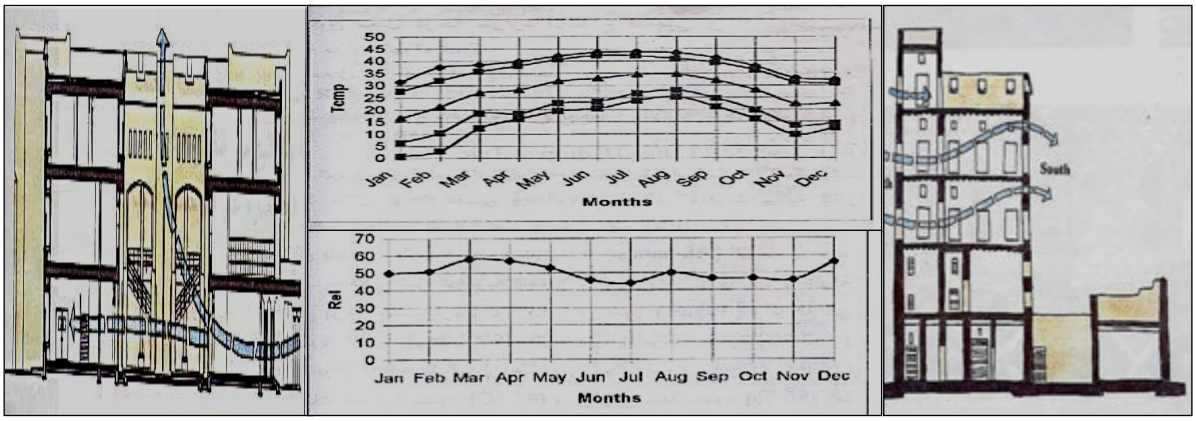

Figure 7: Monthly Average of Temperature (Al-Saggaf, 2004)

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The city plan usually has large squares that function as a storage of pure moderate cold air. The narrow zigzag roads, which are open into vistas with closed end, do the same function of the squares. They store the moderate cold air at night and do not let it leak at the first blow of air (Figure 7). This occurs in the case of network planning of large streets. It becomes clear here that the traditional planning is better than the vertical network planning in the large street. However, the traditional planning does not assimilate traffic cars, but there are some solutions to this problem. For instance, a ring road from which internal streets with closed ends are branching can surround the housing area. Another solution is concept suggested by Doxiadis (1968); it puts forward the idea of preserving the characteristic traditional layout inside the public square.

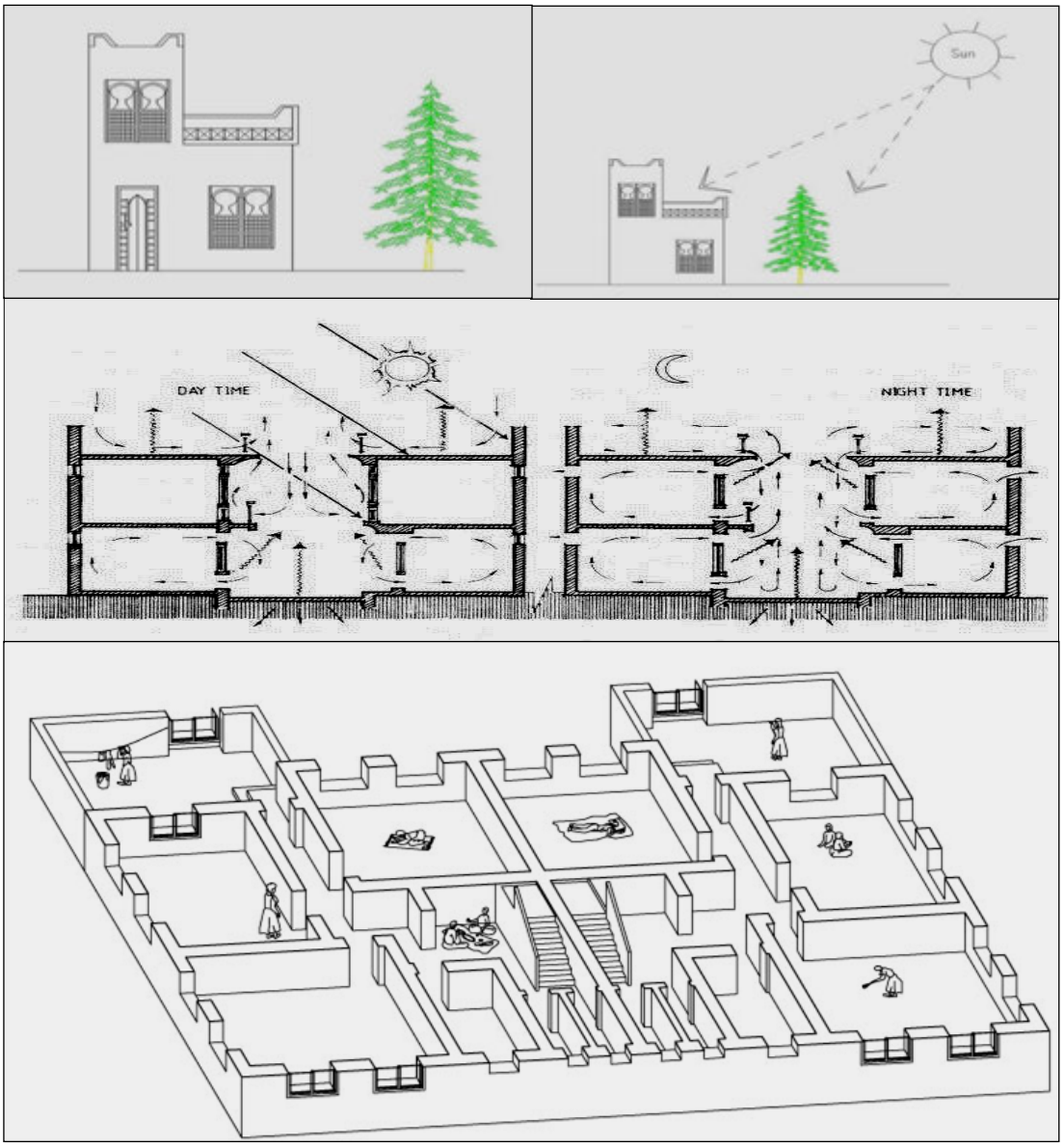

Figure 8: Running of Current Breeze at Day and Night in Clay Building

5.1 The Needs of Ventilation

Performance of mud clayed buildings in Wadi Hadhramout within the hot and dry environment takes place through its adherence with the urban planning of the single constructed mass through which the narrow shaded alleys pass like in Shibam city. The outside surface of these buildings is least exposed to the external environment surface are painted with Lime that possesses high reflective property compared to other materials (Figure 8).

Response of the thermal traditional building to the high temperature difference of day and night occurs through the heavy massed walls and roofs of high thermal insulation and high thermal storage capacity,(Fathy,1986). The clay building elements absorb the short wave radiation of the solar energy preventing heat from passing to the inside of the building. The heat is absorbed in these elements during the day and released to the outside atmosphere during the night. Moreover, lime painted surfaces are highly heat-emissive.

Clayed walls are distinguished with walls of other materials in many aspects, e.g. the time lag in conducting heat of clay walls is double to that of concrete walls and the decrement factor is quarter of that in concrete walls. This is caused by the low thermal conductivity of clay that results from its low density due to the air voids that are dispersed in clay after evaporation of water during the drying process. Moreover, specific thermal heat of clay is relatively higher than other building materials. In clayed buildings, much of the heat is released during late night hours to the outside atmosphere where it gets cooler and denser. The high air density causes it to lower into the narrow streets and the open yards where it remains until morning. As such these air masses work like cold storages that supply the buildings, specially the lower levels, with cold breeze that flows to the inside pushing the warm air upwards by the convection process through the top windows,(Leslise,1991).

From the temperature comfort requirement of shading and sun lighting, it is observed that the ideal shape between the masses in the rectangle which longer side extends between the East and the West and which height is not less than any of its horizontal dimensions. The geometrical ratios of space is much important than its orientation, a conclusion that conforms to the field survey of the residential complexes in Shibam city. The idea that rose in designing the building along with the achievements they accomplished from the needs for the dwellers

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has positive effects in treating the weather problems that can be summarized in the following:

1- The limitation of using the external holes and the smallness of its size has effected in preserving the internal suitable heat and without its effectiveness by the increase in the outside temperature in the morning or decreasing it at night.
2- Covering some holes using the oriels has secured the element of the privacy for the dwellers inside the house as long as it restrains from the strength of the nature light and the reduction of the penetrating sunrays into the inside in addition to the beauty aspect concerning the ornamentation of these holes.
3- Using thick walls in the buildings in addition to the construction reason helped in preserving the degrees of temperature inside them in equilibrium way away from the unsteadiness of the outside temperature.
4- Using the protruding for some upper parts of the frontages that extended along the alleyways has formed another way of frontage-wall breakers for the house and gives plastic dimension from the visual point of view.
5- Gathering the buildings in accordance with architectural convenient adjacent system resulting less exposure of the external walls to sunrays, also it resulted shadowing the building to neighbouring areas and protecting the building from the sunrays.
6- The building style is a unique Hadhrami one. It is functional, and formal, (masses, elements and ornaments) distinguished. There is also some overlapping with ancient Hadhrami architecture and the Islamic arts.
7- The mode of the designing of the Hadhrami buildings and its planning and forming characteristics is a sealed mode and vertical in big families expanding and formed with other buildings quarters participated in functional service such as the mosque and the public square.
8- The specifications that distinguished the frontages, which are high and overlook the street (square). The ornaments represented by the oriels. The buildings plastered with lime from the bottom to the top for protection.
9- The wall singularity; hierarchy gradation of the external walls.
10- The architecture structure: the structure in the city is clearly observed homogeneous and symphonic in altitudes and masses and formed the verandas and the beams that connected the buildings, in addition to the minaret (of a mosque) as direction landmarks.

11- The similarity: the buildings are similar in the horizontal structure; the external frontages do not rely on the similarity in the masses or in forming their architectural elements.
12- The symphonic: a continuous horizontal and vertical rhythm in the main frontages.
13- The proportionateness: in the generic formation, masses and superficies, holes in the main frontages.
14- The harmony and compatibility: the simplicity ornamental of the formation in the inside and the outside, and the gradation in the altitudes. The variation in the shape of the holes in the surfaces of the frontages in accordance with the rectangle shape of the holes.
15- The external ornamentation: the ornaments are simple frames around the windows. These ornaments concentrated on wooden leaves for the windows and the doors.

This kind of building is established for the spiritual and social characteristic architecturally and ability to create a sensation and a feeling of the beauty and psychologically content of the softness to touch and creates consonance harmony with surrounding besides the simplicity and flexibility of shaping it (structural and ornamental) with the possibility of making architectural big holes relatively and the varied vacuum shaping masses (dome, cone, adorn…etc).

This study has discussed several thermal properties and heat transfer parameters for various building materials made from mud clay's natural soil. Based on the outcome of the study it may be concluded that:

1. Adobe walls and roofs gain less heat than concrete walls and roofs,
2. Adobe peak's heat gain is also low and takes place when outside temperature declines,
3. Adobe construction enjoys higher thermal features than concrete.

When comparing concrete with the perforated red clay construction we find the second has superior thermal features and, hence, may be its manufacturing is recommended particularly to Hadhramout region as it has superior thermal qualities and can compete with concrete construction.

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6. Advantages of Mud Buildings

The study can summarize the main advantages of using this kind of building construction to the following main advantages:

1. The material are available in large quantities,
2. Low cost materials, so low-income families can afford it,
3. Simple construction techniques may be used when constructing with this system,
4. It is suitable for the construction to most parts of the building,
5. It is non-a flammable material-resistance to fire,
6. It has high thermal capacity, low thermal conductivity, and can maintain comfortable internal temperature,
7. It is a material of low energy usage. Subsequently, it saves biomass fuel and as a result, it conserves the environment.

7. Recommendations of the Sustainable City's Development in Hadhramout Valley

1. Exert efforts to improve the quality of mud-bricks and investigate the feasible and applicable methods to introduce a material that may protect the brick's external surface from the effect of water and sand born winds.

2. Assess the scientific field experiments that use mud-bricks to construct modern houses. This will help realize mistakes and avoid them in the future.

3. Co-operate efforts with research centers and concerned bodies in the field.

4. Utilize existing information to solve any hygienic problem may be found in mud-bricks constructed buildings and study their different impacts.

5. Investigate the interaction between mud and other construction materials such as wood, insulation materials, water, paint, ceramic, etc. bearing in mind that these elements require further investigation to ensure quality performance when used in mud-bricks constructed buildings.

6. Carry out thorough studies in order to establish and develop standardizations for mud-bricks constructed buildings and pass the outcome to the concerned parties. Furthermore, convince decision makers in each country to include these results into the national standardization documents.

7. Provide official support as well as protection to mud-brick constructions, which proved quality and durability when serving local residents. In addition, encourage governments to construct some of its projects using mud-bricks.

8. Provide official and private financing to specialized studies that are aimed at developing this material. This will encourage researchers to announce the outcome of their research and publicize the characteristics of mud such as fire proof and sound insulation. Moreover, such studies will find solutions for some unfavourable elements such as weak resistance to earthquakes and other issues that may be of different interest from one country to another.

8. Conclusion

The urban planning of the city is harmonious and rhythmic in heights, objects, and the morphology of minarets, in addition to the bridges, which connect the buildings, and the minarets. The elements of the urban composition consist of market, shops, *Al-Jamea AlKabeer* (the big mosque), mosques, buildings, public squares, and the castle. The type of building design and characteristics of planning, is enclosed and vertically directed in building. It forms with the other buildings zones sharing similar public services functions, mosques, and squares. The composition type of religions service building is different in plan. The form of the building is square and rectangular opening in the outside e.g. the open part in the mosque, the coverall part (corridors), the distinctive general characteristics of facades, the main facades of the buildings generally lookout on the streets or squares. Patterns are represented by windows (*Mashrabiya*). The buildings are painted with limestone for protection. The external walls are generally pyramided. There is simplicity of similarity and difference element, in the pattern morphology inside and outside and gradual heights. There is also a variety in the openings forms on the surface of the facade, by changing the size and the position of rectangular form of the openings, along with the harmonious colour distribution. The environmental control of climate; the architectural type is also rich in its experiences of the ability to endues environmental climatic control in creating heat given comfort the direction of building and functions, selection of building materials having thermal isolation ability, volume control of acquired heat, air movement activation through narrow low and high openings. Make it out standing in design and construction. The overall the researcher concludes that the Hadhrami, Yemeni city model is unique and characteristic morphologically

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and functionally objects, elements, and pattern. It shows interrelation of ancient Hadhrami, Yemeni architectural and Islamic art along with the perpetuating experience laden with knowledge accumulation.

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Dr. Anwar Ahmed Baeissa is an assistant professor at Department of Architecture & Environmental Planning, Faculty of Engineering & Petroleum, Hadhramout University of Science & Technology (HUST), Yemen. He earned a Bachelor and Master of Architecture (B. Arch & M. Arch) degrees in 1998 from the Odessa State Academy of Civil Engineering and Architecture, Ukraine, USSR. He worked from 1999-2003 as instructor at department of Architecture & Environmental, Planning and he had been awarded a PhD degree in 2009 from the University of Science Malaysia (USM), Penang, Malaysia. His research is focused on evaluations of space planning towards habitable house designs for low-income group.

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