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Ancient Climatic Architectural Design Approach

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Abstract. Ancient climatic architecture had found out a series of appropriate responses for the best compatibility with the critical climate condition for instance, designing 'earth sheltered houses' and 'courtyard houses'. They could provide human climatic comfort without excessive usage of fossil fuel resources. Owing to the normal thermal conditions in the ground depth, earth sheltered houses can be slightly affected by thermal fluctuations due to being within the earth. In depth further than 6.1 meters, temperature alternation is minute during the year, equaling to average annual temperature of outside. More to the point, courtyard buildings as another traditional design approach, have prepared controlled climatic space based on creating the maximum shade in the summer and maximum solar heat absorption in the winter. The courtyard houses served the multiple functions of lighting to the rooms, acting as a heat absorber in the summer and a radiator in the winter, as well as providing an open space inside for community activities. It must be noted that they divided into summer and winter zones located in south and north of the central courtyard where residents were replaced into them according to changing the seasons. Therefore, Ancient climatic buildings provided better human thermal comfort in comparison with the use contemporary buildings of recent years, except with the air conditioning
Keywords: Architecture; ancient climate; thermal; design; courtyard; earth sheltered.

1. Introduction

Undeniably, climatic architectures in most parts of the world date back to thousands of years of history (Schoenauer, 1981). In ancient climatic buildings, the climatic factors have always been important issue in the design to provide a series of appropriate responses according to the best compatibility between the environment and human thermal comfort (Suter, 2006). Furthermore, in traditional architecture, based on geographical location, buildings were designed to deal with the outside environment through the roofs, external surfaces, windows, ventilators, courtyards, basements and other elements (Adil, 2001). Nevertheless, with the advent of modern architecture and the increasing usage of HVAC (heating, ventilation, and air conditioning) systems, the importance of climate was receiving less attention and similar architectural patterns were used in different parts of the world with diverse climatic conditions (Lili et al, 2011). As a result of these challenges such as the reduction and depletion of non-renewable energy sources of fossil fuels on the one hand, and pollution in cities and environmental impacts on the other hand, attention to the climatic design was re-introduced in the 21th century (Nahla Adel and Elwefati, 2007).

2. Discussion

In this section, two types of traditional techniques on ancient climatic designs with special climatic considerations such as critical conditions are reviewed and the strengths and weaknesses of these approaches in relation to the construction of modern buildings are discussed.

2.1 Courtyard Houses Approaches

2.1.1 Overview

Courtyard houses – as four season buildings – provide controlled climatic spaces. Due to its inward-facing form on four sides closed in by enclosed walls, heat transfer from the inside to the outside and outside to the inside is limited (Okhovat, 2010). Based on creating the maximum shade in summers and maximum solar heat absorption in winters, these buildings are divided into summer and winter zones located in the back or front of the sun path, respectively. It means the courtyard is situated in centre of building and the summer and winter parts are located in two different directions of the central courtyard where the residents were re-located into these zones according to the changing seasons (Meister, 2004). In the summer, because of the particular orientation of the summer zone, the direct solar radiation can be avoided and only diffused solar radiation and sunlight sparkles should be allowed for day lighting purposes. On the other hand, due to the orientation of winter zone in front of the sun path, direct solar radiation is entered into the house by windows facing the sun (Adil, 2001).

Figure2.1. Three-dimensional picture of central courtyard house

2.1.2 Previous Case Studies

Few case-studies have demonstrated why the thermal comfort conditions inside courtyards in hot-arid and temperate climates are significantly cooler than the prevailing ambient weather conditions. Ahmad et al. (1985) conducted an ancient courtyard house within the sixth century and compared it to a modern detached house under summer and winter climates at Ghadames, Libya. In the summer, the outside temperature was between 20 °C and 40 °C while during this time the inside temperature of the courtyard house was consistent at approximately 28 °C. Nevertheless, the temperature of the inside of the modern detached house was between from 34 °C and 39 °C. In the winter, the ambient temperature range was from 4 °C to 23 °C whereas the temperature inside the traditional courtyard house has remained almost stable at 12 °C. In contrast, in the modern house, during the winter, it was between 12 C and 14 °C.

Reynolds and Carrasco (1996) monitored an ancient courtyard building in Bornos, Spain exposed to a hot and dry summer climate. For three days in August, the indoor temperature ranged between 26 °C and 29.5 °C whereas the outdoor temperature has been from22 °C to 44 °C. The Reynolds and Carrasco study clearly demonstrated the thermal benefits of the courtyard houses, which resulted in improved indoor thermal comfort.

Golany (1988) investigated the thermal performance in one of the courtyard houses in Magmata, Tunisia. The thermal data provided by him showed when the maximum outside temperature was near 42°C, the temperature in the summer part of the courtyard was almost 25 °C that means inside it was about 17 °C cooler than the outside. He also measured the temperature of this courtyard house in mid-winter when the outside was 7 °C, but the inside of the room was about 9 °C warmer than outside by 16 °C.

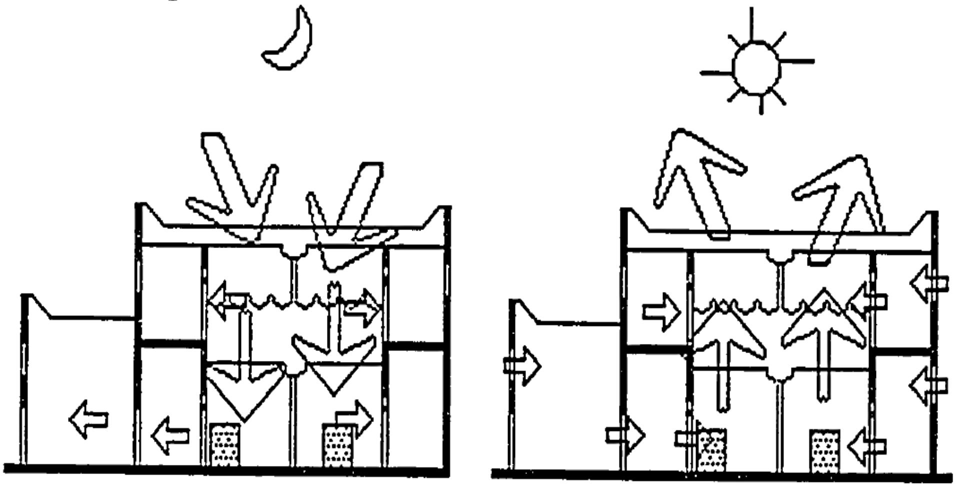

Figure2.2. Section through the traditional courtyard house explaining (Aleid, 1994)

2.1.3 Benefits

The studies of the courtyard houses indicate that these strategies have high efficiency in providing cool indoor in the summer and warm indoor in the winter for inhabitants (comfort zone). Moreover, courtyard building is as an energy efficient architectural design in critical climate conditions, with the possibility to achieve as much as a 30 % reduction in cooling and heating costs through careful landscape planning (Golany, 1988). Hence, this architectural method can be used to provide annual energy saving and achieve appropriate thermal comfort for residents (Adil, 2001).

2.2 Earth Sheltered Houses

2.2.1 Overview

One often neglected technology is underground buildings. This part of research defines underground buildings as a one types of ancient climatic approaches in both hot and cold regions as an alternative to conventional above-ground structures to reduce energy demands as well as peak load requirements. This approach is not new technology in architectural history; however, in terms of optimizing energy consumption and attention, it will be an innovative idea. The use of earth sheltered houses received attention only after the energy crisis in 1973 because of its compatibility with the climatic environment, its surroundings being a climate control strategy and energy savings approach followed in it. In the United States, military installations, in Japan and Stockholm, some shopping centres, in Norway and Sweden, oil storage spaces are some examples of earth sheltered public and private buildings (Golany, 1983).

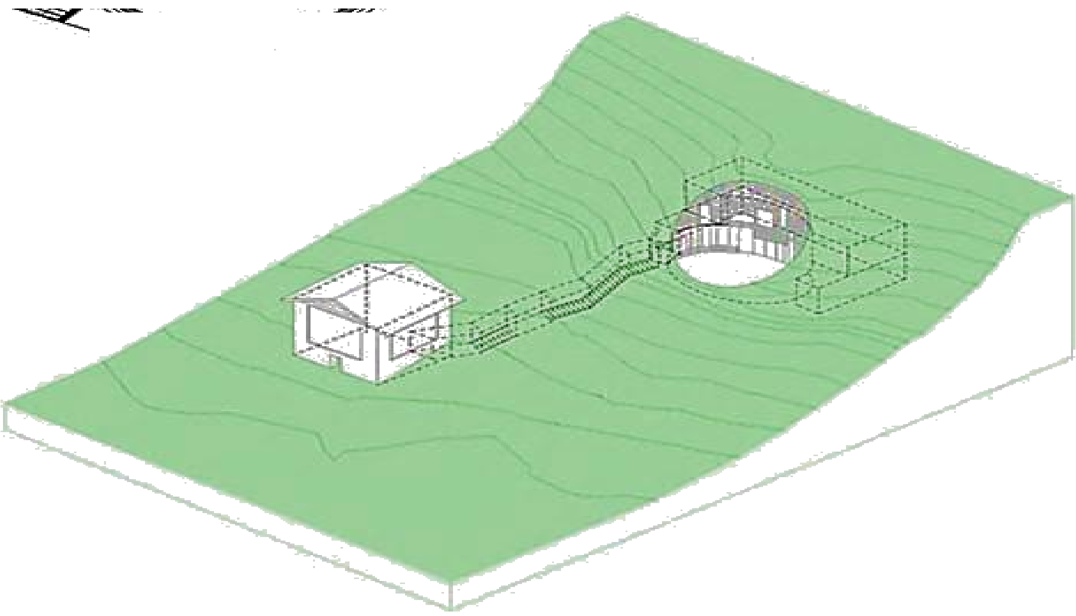

Figure 2.3: Section of Underground Houses

2.2.2 History of underground buildings

Although, this method has been used in some cultures as a successful solution to deal with bad weather conditions for thousands of years (Goldfinger, 1969) , the use of earth depth and soil thermal stability, as one of the elements of thermal control systems, turned into a popular architectural method from the October oil embargo of 1973 (Labs, 1988).

The most historical significance of these approaches can be found in three major regions: Northern China, the Goreme Valley of Cappadocia in Central Turkey, and in Tunisia. These three areas share a hot-arid climate that is identified by fluctuating temperature, diurnal and seasonal weather (Golany, 1988).

2.2.3 Function of Earth Sheltered Houses

Owing to stable thermal conditions at depths in the ground, underground houses are hardly affected by thermal fluctuations (Adil, 2001).

With this strategy -covering the building envelope by soil- heat transfer between the inside and outside is limited and the building is isolated from the direct impacts of the critical climate. Therefore, it can provide a safe and comfortable living environment for its residents (Carmody and Sterling, 1984).

The equation shows for estimating subsurface temperatures as a function of depth and day of the year (with cosine expressed in rad) (Labs, 1979).

$$T_{(x.t)} = T_m - A_s\, e^{-x\sqrt{\frac{\pi}{365\alpha}}} \cos [\![\{ \}] \frac{2\pi}{365}\left[t - to - \left(\frac{x}{2}\right)\left(\sqrt{\frac{365}{\pi\alpha}}\right)\right]\Big\} \qquad ..... (1)$$

Where $T_{(x,t)}$ is the subsurface temperature at depth x (m) on day t of the year (°C), T_m the mean annual ground temperature (equal to steady state) (°C), As the annual temperature amplitude at the surface (x = 0) (°C), x the subsurface depth (m), t the time of the year (days) where January 1 = 1 (numbers), t_0 the phase constant, corresponding to the day of minimum surface temperature (days), and α the thermal diffusivity of the soil (m^2/day).

Moreland (1975) and others use variants of the equation. When the variables are measured from field monitoring, the method generates errors of no more than ±1.1 ◦C (Labs, 1979).

The resulting temperature profile at different depths can now be shown in graph and it is compared with the annual average of air temperatures.

The graph below shows that in depth further than 6.1 meters, temperature alteration is minute during the year, equalling to average annual temperature of outside.

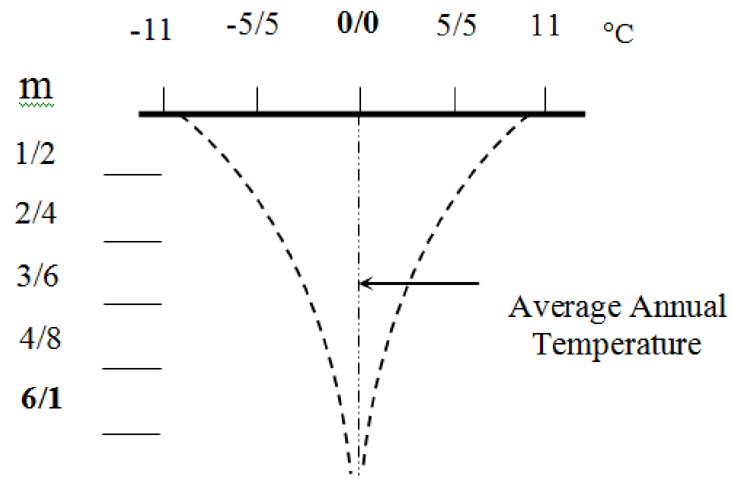

Figure 2.4. Underground annual temperature fluctuations versus depth

2.2.4 Previous case studies

One study in a residential building with a two-storey in Kuwait shows that the infiltration can be responsible for around 53% of the sum total peak cooling load On the other hand, in underground houses, infiltration rates are considerably decreased, thanks to its buried walls. Besides, heat gain via the roof and walls is significantly reduced since the temperature of the soil is lower than the outside temperature in the summer (Fereig and Younis, 1985). The soil temperature in Kuwait is almost 31 °C at 3.0 metre depth in mid-July while the outside temperature reaches nearly 45 °C. Furthermore, shading and covering with vegetation influences the soil temperature, reducing it to lower than the measured 31 °C (Meister, 2004).

In the case study in colder climates, according to Kumar et al. (2007), it was considered that during winters, the amount of heat loss in the earth supported structure was less than that of on-ground structures, indicating through results that the floor surface temperature risen by 3°C for a 2.0 m deep earth supported structure because of lower heat transfer from the building elements to the ground. Hence indicating than the passive heat supply from the ground even at the extreme cold temperatures thus is a factor for energy saving in underground buildings.

2.2.5 Advantages

Most researchers on earth sheltered housing agree with the idea that underground buildings provide energy savings by reducing heating and cooling loads annually in comparison with known conventional structures (Carmody and Sterling, 1984). Carpenter (1994) states that the earth sheltered buildings have the best potential of energy savings in any design. Not only is the temperature difference between the exterior and interior reduced, but the building is also protected from the direct solar radiation.

Dodd (1993) climes that the underground houses as a controlled micro- climate provide a comfort zone for habitants according to soil thermal stability. As a result, Energy efficiency according to soil thermal stability, reduction in bills of heating and cooling systems usage and controlling noise and vibrations from the outside are the most important solution of underground buildings.

2.2.6 Barriers

Despite that fact that the underground houses are energy efficiency and have other benefits, they also have some limitations and disadvantages. Several researchers believe that there are some psychological and social difficulties to overcome if underground housing is to be implemented on an extensive basis (Golany, 1983). Aughenbaugh (1980) states that the biggest barrier to the consideration of underground housing is that designer believes people will not accept to live under earth's depth. Although, he claims people will accept these buildings if they know about the provided benefits of underground housing.

3. Conclusion of Ancient Climatic Design

It must be noted that ancient climatic building methods have always paid some respect to the climate. Although, traditional buildings approaches should be considered, evaluated and developed but not copied. That means traditional architectural solutions should be studied, especially, using soil thermal stability factor and special orientations; however, the barriers and restrictions should be removed. In this section, two types of ancient climatic design approaches namely courtyard houses and earth sheltered house were mentioned. The fishbone diagram shows over view of Ancient Climatic Design Approaches.

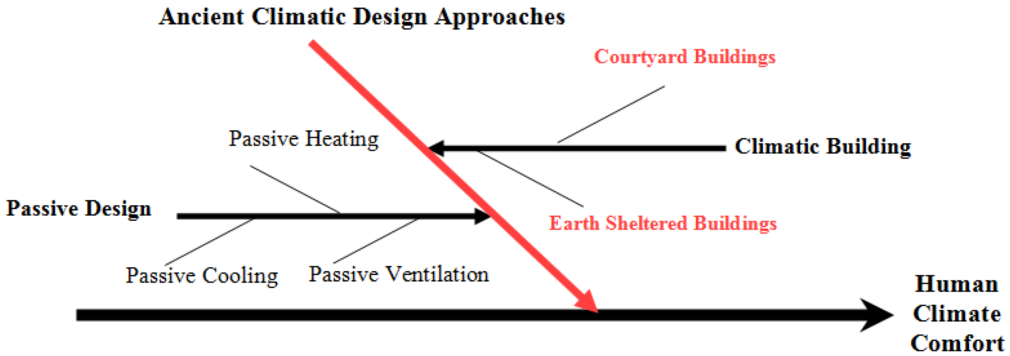

Figure 2.5. Fishbone Diagram of Ancient Climatic Approaches

There are some disadvantages of both ancient climatic method mentioned earlier. For instance, the earth sheltered houses have significant restrictions, including impossibility of using landscape on the ground during temperate days, lack of suitable access to the ground surface and natural light in all or parts of their interior spaces which make difficult condition for living. Likewise, courtyard houses provide controlled climatic spaces for residents in the summer and winter with different zones. Still the movement between different zones has the difficulty of furnishing handling from the summer zone to winter zone and vice versa located in different direction in the yard during the year. The SWOT (strength, weakness, opportunities and treat) matrix below discussed the most important inside and outside factors of these approaches.

Table 2.1. SWOT Matrix of Ancient Climatic Approaches

Inside Factors	
Strength	**Weakness**
❖ Best Compatibility In Critical Climate ❖ Minimize Energy Consumption ❖ Improve Thermal Comfort	❖ Construction Difficulties Today ❖ Imposing Residents Relocation ❖ Facilities Weakness
Outside Factors	
Opportunities	**Threats**
❖ Prevention of immigration	❖ land constraints

As can be seen, the major strengths of the traditional design is that of improving Thermal Comfort and Minimizing Energy Consumption while the most important weakness is imposing residents relocation inside the building. However, relocation/movement of residents inside of both courtyard buildings and underground houses has been one of the fundamental factors to meet human thermal comfort needs.

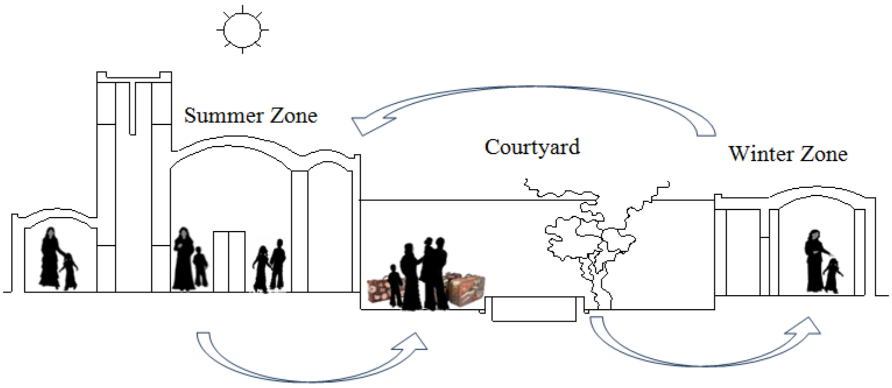

Figure 2.6. Resident movement between summer and winter zones in courtyard houses

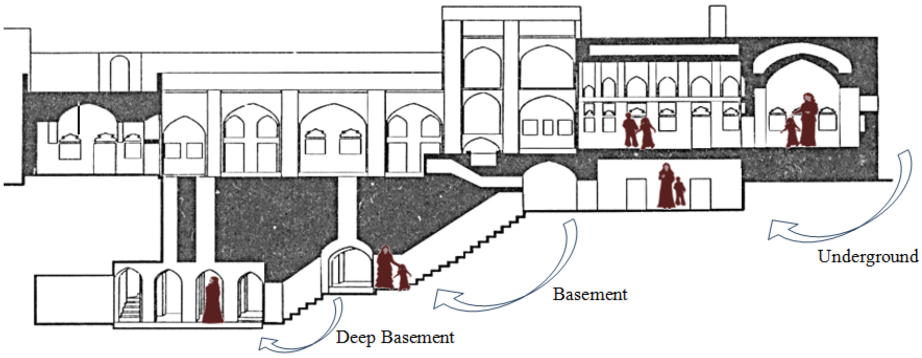

Figure 2.7. resident movement between deeper level

To sum up, to find the best solution for the design a modern climatic building that is efficient for modern human living, the traditional strategies should be examined while at the same time their restriction should be removed.

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Древне-климатический архитектурный подход к дизайну

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Аннотация. Древняя климатическая архитектура знала ряд соответствующих мер для лучшей совместимости с критическим состоянием климата, например, проектирование «земля защищенных домов» и «двор домов». Они могут обеспечить человеку климатический комфорт без чрезмерного использования ресурсов топлива. Вследствие нормального теплового режима в глубине земли, защищенные землей дома могут быть слегка затронуты тепловыми флуктуациями. Во дворе дома были многочисленные источники освещения, которые действовали в качестве поглотителя тепла летом и радиатора в зимнее время, а также предоставляли открытого пространства внутри двора для общественной деятельности. Следует отметить, что они подразделяются на летние и зимние зоны, расположенные в южной и северной части центрального двора, где жители находились в соответствии с изменяющимися сезонами. Таким образом, климатические древние здания обладали лучшим тепловым комфортом для человека по сравнению с использованием современных зданий последних лет.

Ключевые слова: архитектура; древний климат; тепло; дизайн; двор; защищенная земля.