Towards achieving green buildings in developing countries based on a traditional approach with reference to the hot-arid climate

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Abstract

Despite the fact that green buildings have become an important architectural trend in the 21st century, they still constitute a tiny subset of existing buildings in developing countries. Buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting and air conditioning. Developing countries are still facing unprecedented environmental and financial challenges in their pursuit of achieving rapid urban growth. The combined effect of the business model of "growing at any cost" adopted by these countries has resulted in the deterioration of their environment, manifested in the forms of depleting eco-systems and increasing climate vulnerability. There is growing realization of the urgency to move away from the current situation towards green buildings. This research argues that green buildings have much to learn from the buildings of the past. The research methodology of this paper adopts an analytic approach to environmental solutions in traditional architecture. The key emphasis on the design of greens building lies in energy-saving and nature conservation. The findings of this research reveal that the traditional architecture approach can be used as the main base for green buildings in developing countries. Furthermore, a reconsideration of a traditional architecture approach can provide crucial solutions towards achieving green buildings in developing countries.
Keywords: achieve green buildings, energy, climate, traditional architecture approach, developing countries.

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1 Introduction

People always modify their harsh environments into a favourable setting for sustenance. In this process, the energy used is transformed from one form to another with residual effects threatening their existing formation on the earth. This uncontrolled negative residual effect resulted into the process of GHG (greenhouse gases emissions) giving way for climate change. The determinant factor of this is a result of economic and social improvement of human conditions which is evolving and non-ending. Instead it has to be guided in certain way to reduce the negative effects of the residual formation. There is growing realization of the urgency to move away from the current situation towards a new development paradigm that focuses on improved quality of life and ecological sustainability.

Arguably, the emergence of a green building would be of much benefit to the developing countries, where there is an urgency to make a 'green philosophy' deeply rooted in everybody's mind. Developing world is the home to 80% of the world's population. It considers as one of the fastest growing regions in the world in terms of economic development, rapid urbanization, population growth, energy demands, and greenhouse gas emissions. How the leaders and population of the developing countries will respond to the challenge of green building will affect the future of the entire global environment.

While developing world is the globe's fastest growing region, it is one of the major sources of greenhouse gases, and the region is likely to be severely affected by the impact of global warming on regional economies, environment, society and the lives of ordinary citizens. The forecasts of *UN-Habitat* (UN Report, 2008) indicate that over 90% urban growth over the next 15 years will occur primarily in developing countries, and there mainly in cities: By 2020, the region will account for more than half of the world's urban population [1]. Developing countries will consume 65% of the world's energy by 2040 [2]. About 57% of global greenhouse gas emissions originated in developing countries, with China and India accounting for a third of the worldwide carbon spews [2] (figure 1). Accordingly, climate change presents this region with tremendous challenges, probably more so than any other region on the whole world. On the other hand, in some countries of Africa, yields from rain-fed agriculture could be reduced by 50% by 2020. At the local level, many people are likely to suffer additional losses to their livelihoods when climate change and variability occur together with other stresses, such as conflicts [3]. Thus, the effects of climate change will first and foremost affect the population in the developing countries. There is no doubt that the source of conventional energy exemplified in the fossil fuels is a non-renewable energy, in addition to the high cost and the negative impact of their use on the environment [4]. Thus, green buildings could help to solve some of the pressing problems caused by rapid urbanisation and climate change.

The rapid urbanization in developing countries has been typified mainly by an adaptation of alien solutions to immediate urban crises. Traditional architecture was built to provide shelter from the forces of nature and comfort to their occupants, with the minimum amount of resources. The use of local material, construction techniques and harmony with their surroundings was an integral part

of their design, which not only respected but took advantage of local climatic conditions. Hence, such buildings are not only warm in winters and cool in summers but are also more economical to build and maintain; all these qualities together make them environmentally friendly and sustainable [5].

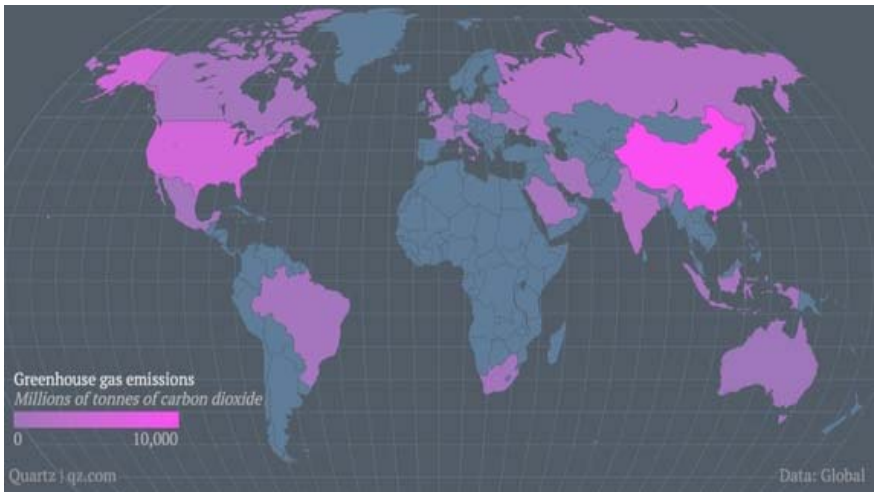

Figure 1: The top twenty carbon polluting countries in 2012 [2].

2 Methodology

Mostly, this paper adopted the qualitative data survey as a research approach. It is also referred to as the interpretative, constructivist, or post- positivist approach. This approach guides the research to gain a holistic overview of the context under exploration; including its logic, its function, its technique, as well as its explicit and implicit rules. This research draws on multiple sources of data. It uses drawings and photos of existing examples as a medium for acquiring knowledge of the inherent techniques of traditional architecture. This paper therefore presents the findings of knowledge acquired from conducting an analytical survey of traditional buildings in developing countries. It aims at exploring the potentiality of achieving green buildings based on a traditional architecture approach with particular reference to hot-arid climate.

3 The notion of green buildings

The notion “green” and “sustainability” that are often used interchangeably, have gained recognition in the construction industry within the past decade, as the world has become more aware to the global climate change. Globally, buildings are responsible for approximately 40% of the total world annual energy consumption.

Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of CO_2 and NO_x emissions and CFCs triggered a renewed interest in environmentally friendly cooling, and heating technologies. This problem forces developing countries to adopt a number of policies that enhance energy efficiency and apply baseline parameters in accordance with international standards.

The idea of green building can be traced to the energy crisis and environmental pollution concerns of the 1960s and 1970s [6]. Recently, green building becomes an important architectural approach in the 21st century. The key emphasis on the design of the green building lies in recycled material, energy-saving, and nature conservation. It is not only beneficial to human health but also protective for the earth, fulfilling the responsibility of sustainable development. This approach emerged in Europe, and then spread to Japan and North America. Thanks to the lead of certain advanced countries, it has become the mainstream of the architecture in the 21st century worldwide. In the face of pressing environmental and economic challenges, many serious efforts to promote green buildings have been intensifying in recent years. Building on this momentum can help to accelerate progress towards sustainable development, for example, more sustainable use of natural resources, efficiencies in the use of energy, and valuation of ecosystem services. According to the US Environmental Protection Agency (EPA); "Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building" [7].

There are several definitions of green buildings. In general, green buildings can be defined as design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas: site, water, energy, materials and comfort. Clearly, there cannot be one singular definition of the notion 'green building', as the various different concepts have always expressed a wide diversity of possible positions and meaning. Providing a rigorous definition for green building can be challenge with recent studies illustrating the wide variety in its interpretations. One of the main reasons for this relates to the numerous definitions for the notion of green building. The term 'Green building' has multiple meanings – some of which are complementary while others are competing. This has led to confusion over what the term means, what is to be green, by whom, for whom and what is the most desirable means of achieving green building. In the recent debate about green building, the tension between the ecological and the economic has been an obvious one. Arguably, eco-civilization emerges to be a reflection of society on global industrialisation.

Green Building provides many advantages. These advantages including marketability value, energy efficiency performance, less emissions, adequate day lighting and good distribution, less glare, low energy and water consumptions, better ventilation, free from high VOCs, indoor air quality, free from sick-building

syndromes and long lifecycle [8]. Keeping and Shiers [9] discussed the benefits of green building in the refurbishment of commercial property leading to lower energy costs, lower maintenance costs healthier environment that reduces absenteeism. Also, Paumgartten [10] concluded that the high-performance green building is changing the direction of the construction business towards a healthier environment and a cost effective approach on the longer term basis. Green buildings bring together a vast array of practices, techniques, and skills to reduce and ultimately eliminate the impacts of buildings on the environment and human health. These buildings take advantage of renewable recourses such as using sunlight through passive solar, using plants as well as using plants and trees through green roofs.

4 Traditional architecture approach

The terms traditional and vernacular architecture are sometimes used synonymously. Traditional architecture praxis has evolved over a long period of time. It means buildings produced by a local group and serving as a frame-work for their daily life. Every climatic zone has its own particular type of buildings. For example, traditional architecture in North African and the Middle East has very high thermal mass and small windows to keep the occupants cool. In many cases also includes chimneys to draw air through the internal spaces. Such specializations are not designed, but learnt by trial and error over generations of building construction. Ironically, this technique exists long before the scientific theories which explain why they work. Traditional architecture is created to protect inhabitants from a harsh climate. It is dependent on passive energy and natural resources, such as sun, wind and earth. Passive energy involves the use of natural energy sources for environmental, healthy, and economical reasons. Traditional architecture represents a living witness for the responsiveness of this architecture to the local environment. In developing countries, traditional architecture is based on modifying ambient environment to protect the inhabitants. Protection is needed from intense solar radiation, extreme temperatures, and dusty winds. The potential of green building in traditional architecture approach emerged through modifying and getting adapted to environmental factors, in order to create a comfortable indoor environment. In other words, climate was a major factor in the formation of traditional architecture in developing countries, where several responses to climatic conditions such as court yard houses can be found.

The basis of a significant portion of the contrast in passive and active design lies in the pedagogical relationship of the development of passive strategies from traditional prototypes and practices [11]. Basically, traditional architecture in developing countries depends on passive design. Techniques employed in traditional architecture approach are compacted urban form, courtyard as a thermal regulator, material efficiency, natural ventilation, and thermal mass. These techniques are constantly evolving and may differ from region to region. It can be argued that traditional architecture can be the baseline in developing green building approach in developing countries. Aesthetic qualities as an important

factor of green building are inherent in traditional architecture. Aesthetic quality is the philosophy of designing a building that is in harmony with the natural features and resources surrounding the site. The following sections will discuss the techniques employed in traditional architecture with particular emphasis on hot-arid climate.

4.1 Site planning and building orientation

In selecting a right building orientation for a hot-arid climate, where most of the developing countries exist, the purpose is to minimize the internal daytime temperature and to produce shaded exterior space. Building and their continuous outdoor living spaces are oriented in a defensive posture against the wind-borne dust. To plan any site, the position of the sun must be determined for all hours of the day at all seasons as well as the direction of the prevailing winds, especially during the hot season. For the direct sun rays, it is sufficient to know the angles of declination and altitude for the summer and winter solstices and the autumnal and vernal equinoxes. In addition, there will be reflection from adjacent buildings and wind shadowing by clusters of buildings, which contribute to specific microclimate for each building location.

Traditional urban fabric is organic; thus most of the plots were irregular. To obtain the internal courtyard that is the central design for traditional houses, the regular geometric courtyard is the first to be planned. Then passageways and rooms are to be arranged around the courtyard. The irregular parts and undesirable angles are modified by changing the walls depth that may be used as shafts, service areas, niches, cabinets, or fixed furniture. Organic compact urban fabric with attached buildings provides protection and safety for inhabitants especially within the neighbourhood community. Neighbour rights and privacy were preserved.

4.2 Courtyard as a thermal regulator

Courtyard houses have an ancient history in Mesopotamia and Egypt thousands of years B.C. Essentially, the courtyard house, which consists of rooms on three or all sides of an open atrium, is associated with Arab culture, but its distribution extended between Sale and Marrakech in Morocco to the West, and India to the east [12]. The philosophical design of Traditional courtyard house is based on attaining two strategies: environmental control and cultural significance. These two strategies influenced the house layout, spatial relations, and architectural details. Courtyard provided an adequate climatic and social solution; it provides shading and privacy in an open space. Most of daily facilities are located at the courtyard. The courtyard represents a constant feature of traditional architecture in most of the Islamic World: it is however, developed in different ways as influenced by existing local traditions, construction materials and environmental factors [13]. The building envelope of the courtyard house is inward looking. Environmentally, courtyard is a thermal regulator, thus exposure to the sun is to be avoided and courtyards are to be kept small and overshadowed by high walls, wide eaves and foliage (figure 2).

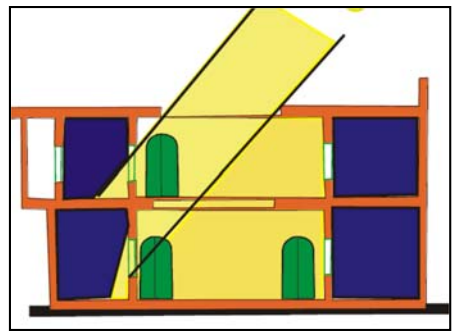

Figure 2: Protection from the sun in the courtyard house (source: author, 2014).

In hot-arid climate, where most of the developing countries locate, courtyard functions in three main phases. As illustrated in figure 3, during the first phase, the cool night air descends into the courtyard and fills the surrounding rooms. Building structure even furniture are cooled at night and remain so until late afternoon. In addition, the courtyard loses heat rapidly by radiation to the clear night sky. During the second phase, at midday, sun strikes the courtyard floor directly. Some of the cool air begins to rise and leaks out of the surrounding rooms. This induces convection currents that may afford further comfort. The courtyard now begins to act as chimney during this time when the outside temperatures are highest. During the third phase, the courtyard floor and the rooms get warmer and further convection currents are set up by late afternoon. Most of the cool air trapped within the rooms spills out by sunset. During the late afternoon the street, courtyard, and rooms are further protected by shadows of adjacent structures. As the sun sets in the hot arid climate, the air temperature falls rapidly as the courtyard begins to radiate rapidly to the clear night sky. Cool air begins to descend into the courtyard, completing the cycle.

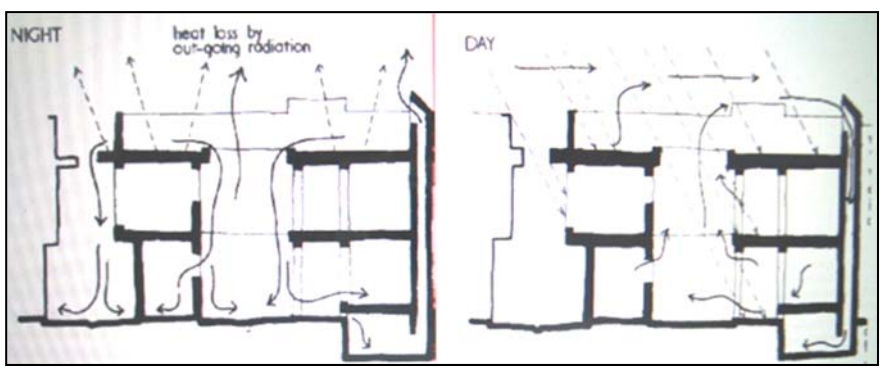

Figure 3: Thermal performance of the courtyard in a traditional house [15].

4.2.1 Building envelope

Building envelope in traditional architecture is the main element to protect from a harsh climate. Simply, it is the barrier between the conditioned and unconditioned environment of a building. There are three main functions of the building envelope. These include resisting heat transfer, reflecting sun rays and providing pleasant indoor environment. The envelope of the traditional building is inward looking. For example, a traditional courtyard house is a type of house where rooms, kitchen and bathroom are disposed around a central courtyard. The exterior walls usually are windowless or have a few openings, where the main rooms of a courtyard house often open onto the courtyard. Windows of upper storeys overlooking the courtyard are often larger, may project considerably, with a wooden lattices device, and must not overlook neighbouring courtyards or terraces. In traditional building, the Window–Wall–Ratio (WWR) should not be more than 25%. Effective day lighting is possible with a lower WWR.

4.2.2 Building materials

A key part of traditional buildings is the use of dry local construction material. Traditional building materials, such as stone, brick, palm trunks, and clay are natural, so they are typically low in embodied energy and toxicity. Thus, these materials result in reduced maintenance and replacement costs over the life of the building, conserve energy, and protect occupant health. Moreover, traditional building materials are better suited to climate and recyclable. Water is scarce in hot-arid areas, thus the solution prescribed has been to adopt dry materials. Traditional building materials such as such stone and bricks are heavy. Stone has been used as a building material for thousands of years. It is a highly durable, low maintenance building material with high thermal mass. Hence, stone is good thermal insulators especially when used as thick walls with minimum external openings (figure 4).

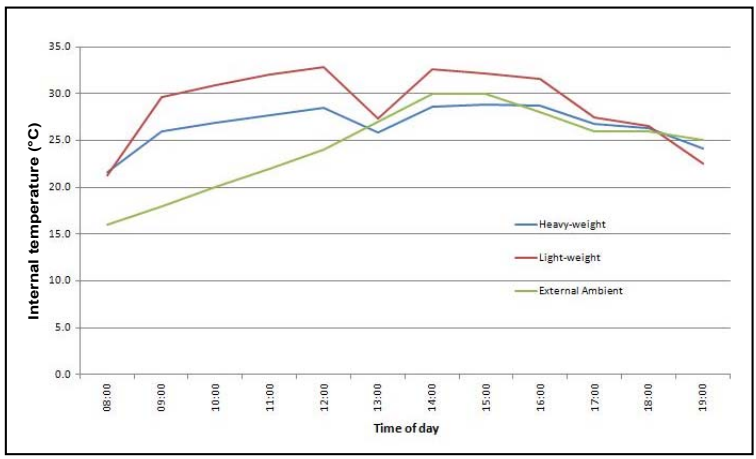

Figure 4: Effect of heavy-weight and light-weight construction materials on the indoor temperature [16].

4.2.3 Natural ventilation

Ventilation in hot-arid climate is important, especially, when the air is cool. Thus, natural ventilation is driven by the natural forces of wind and temperature. Courtyard is an essential element for ventilation and daylight (figure 5). The courtyard should be proportioned to be mostly shaded, and contain cooling elements such as trees, soft paving and water fountain. Natural ventilation was one of the passive cooling strategies that traditional architecture employed to create comfortable indoor climate through evaporative cooling. Wind has been given much attention in the traditional approach. Traditional houses are oriented with respect to prevailing wind (figure 6). Blank facades are oriented to shield the outdoor living spaces from the hot winds while allowing adequate winter sunlight to penetrate the living zones. Wind movement and humidity also are important and should be considered simultaneously with the direct and indirect effects of the sun. Wind towers are the main natural ventilation features, along with courtyard and air pullers, formulate a complementary natural ventilation system for the house. Wind towers as their name implies, are ventilation tools used for obtaining natural cooling. They have been used in developing countries such as Egypt, Iraq and Iran.

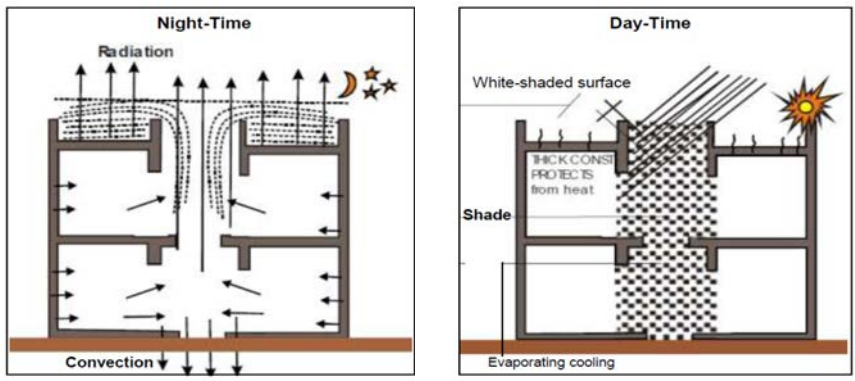

Figure 5: Ventilation in the traditional courtyard house (source: author, 2014).

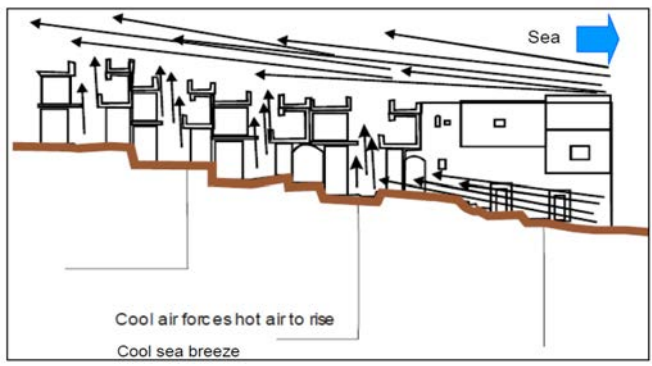

Figure 6: Ventilation in the urban compacted settlements (source: author, 2014).

In winter, where the air movement is not required, dampers are easily shut and the wind catchers' openings covered. A typical wind tower resembles a chimney, with one end in the ground floor and the other end rising from the roof. The upper part of the tower is divided into several vertical air passageways that germinate in openings in the sides of the tower. The design of the wind tower differs in the upper side, the cross section of the air passages, the placement and number of the openings and the placement of the tower with respect to structure it cools. Openings in the lower part of the wind tower open into the ground or first floor in the central hall or the family master room. The flow of air through different parts of the building can be controlled by opening or closing the openings grillers upward and downward (figure 7).

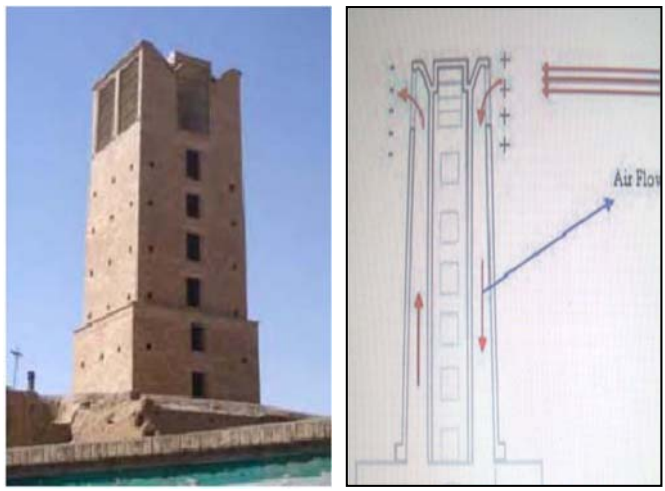

Figure 7: Movement of wind in the wind tower (source: author).

4.2.4 Thermal mass

Thermal mass is the ability of a material to store heat [14]. Simply, it means utilizing mass thermal storage of the earth to absorb heat during the warmest part of a periodic temperature cycle and release it later during a cooler part. Mass-effect cooling is one of the most important passive energy techniques that had been used in developing countries for a long time to provide thermal comfort. It can be achieved by dampening out interior daily temperature swings, delaying daily temperature extremes, and ventilating the building at night. The basement has to be ventilated efficiently by using wind catchers which is a vertical shaft, opens high above the roof level towards the favourable prevailing winds, with another opening at the basement close to the lowest level of the building (figure 8). The inclusion of thermal mass elements into traditional buildings assists in the reduction of energy consumed in heating and cooling. In addition, thermal mass can significantly reduce the ecological impacts of burning fossil fuels for energy production, as well as reduce costs, improve comfort and reduce or eliminate the need for air conditioning.

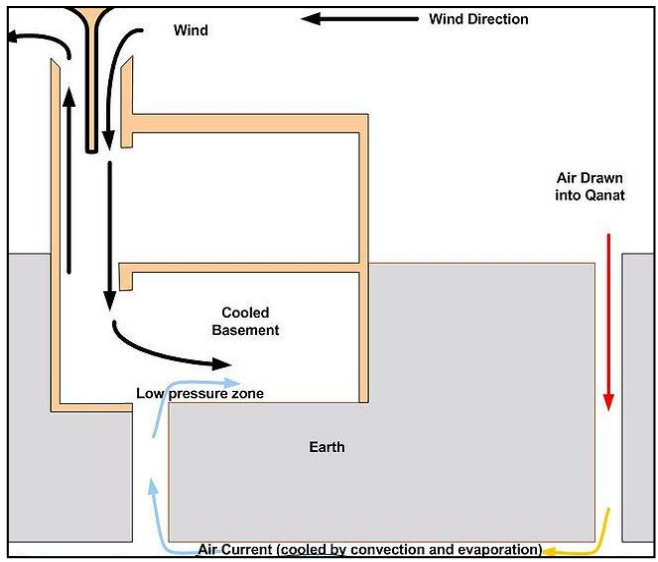

Figure 8: Technique used for evaporative cooling (source: author, 2014).

5 Conclusions

Green building does not always require the latest in smart grid technology, solar panels, expensive recycled materials or the manipulation of LEED scores for environmental design. However, as earlier discussed in this paper, techniques employed in the traditional architecture approach can be the baseline for developing green buildings. Architects and engineers in developing countries should apply the techniques inherent in traditional architecture. This could create buildings that maximise air flow, mitigate their impact on the local environment and provide thermal comfort to residents. The findings of this research confirm that traditional architecture in developing countries can offer practical ideas to enrich the design of green buildings. Traditional building techniques are well adapted to the hot-arid climate in developing countries. In traditional architecture approach, local materials and renewable energy resources have been efficiently used.

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