Passive Solar Design Features for a Zero Energy Home in Babylon, Iraq

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ABSTRACT

Babylon governorate in Iraq (located at 90 km south of Baghdad) is characterized by cold winters and very hot summers. Passive solar techniques could be easily adopted to provide energy-efficient thermal comfort year around. This will reduce the energy consumption and the impact on the environment, and will alleviate the discomfort of residents who have only limited or intermittent power supplies.

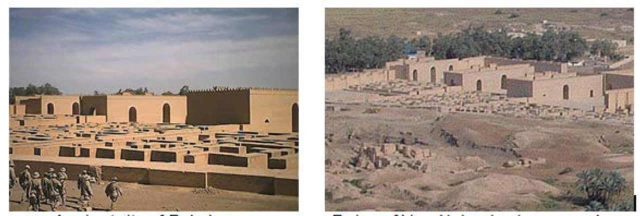
Passive solar design is the key to sustainable building when it can reduce energy loads using techniques that use the sun's energy to heat a home in the cold winter, breezes to cool a home in the hot summer, and simple, logical design and construction strategies. Passive design can reduce temperature fluctuations, improve indoor air quality and make a home drier and more enjoyable to live in – while reducing energy from external sources.

Buildings with good passive strategies are not difficult to design or expensive to build, but they require common sense in working with the environment at hand. The key elements of passive design are: building location and orientation on the site; building layout; window design (day lighting); insulation (including window insulation); thermal mass; shading; and ventilation.

Keywords: House, passive design, solar energy, thermal mass, earth tunnel.

1 INTRODUCTION

Babylon governorate in Iraq is home to the ancient city of Babylon, thought to be one of the world's most ancient cities. Founded long before the great civilizations of Egypt, Greece, and Rome, Babylon was the capital of ten Mesopotamian dynasties starting with the dynasty of King Hammurabi (1792-1750 BC), the sixth king of the first dynasty who reached prominence as the capital city of the great kingdom of Babylonia. The last dynasty, in which Babylon achieved its zenith, is well known for its second king, Nebuchadnezzar II (605-563 BC). Most of Babylon's existing ruins belong to this period. In old Babylon, city planning, cobblestone streets and architecture itself have their beginnings. Figure 1 shows the ruins of ancient city of Babylon and the palace of King Nebuchadnezzar [1]. Figure 1 shows the ruins of ancient city of Babylon and the palace of King Nebuchadnezzar [1]. Today, little is left of the traditional architecture, and most of it is in quite bad shape.



Ancient city of Babylon — Ruins of king Nebuchadnezzar palace

Figure 1: Ruins of Old Babylon

This paper discusses the architecture of traditional Iraqi houses and new houses, and reviews the passive solar heating and cooling technologies suitable for the climate of Babylon, Iraq.

2 HOUSES IN IRAQ

2.1 Traditional Iraqi Houses

In the 19th and early 20th centuries the Babylon, houses took the same form as those in other Iraqi cities. The basic structure of Iraqi houses during that period consisted of thick brick walls. The roof was constructed from wooden poles laid from wall to wall to provide a basic frame, which was covered with palm leaf matting. This was subsequently sealed externally with mud and pebbles. Internally, the ceiling was painted in decorative patterns with strong bright colors. Almost all the traditional houses are courtyard houses inherited from the Islamic era [3].

The main purpose of the courtyard was to protect inhabitants from the severe hot climate. The courtyard house is an architectural concept that controls the environment by creating a domestic micro-climate space within the house. It serves as a light well and air well in which the cool dense night air sinks. It has passive cooling capabilities appropriate to the local climate. All rooms in the house can be entered from the inner courtyard. The best room in the house is called a liwan, which is situated on one side open to the courtyard. In the old Iraqi houses of the wealthy, reception halls could be quite large and well decorated. The house would have what it is called a “shenashil.” Sitting in the shenashil, Iraqi women would enjoy fresh air, see what’s going in the street and be protected from being seen. The shenashil has a microclimate-function as well. As the dark wood gets quite hot in the sun, the air rises and pulls the warm air out of the adjacent rooms, sucking cool air out of the cellar [3]. Figure 2 shows pictures of old style houses.

Figure 2: Old Style Iraqi Houses

Another very important part of the traditional Iraqi home is the sirdab (basement), which served multiple cooling functions. It provided for cool storage, a cooling hall, and cool air through the badgier-sirdab-system.

The badgier, or wind tower, was often used in combination with courtyards and domes as an overall ventilation / heat management strategy. The main upper portion of the badgier is the malqaf, which is the top portion of a capped tower that has one face open to the prevailing wind, enabling the tower to 'catch' the wind and bring it down through the tower into the heart of the building to maintain air flow. This was the most direct way of drawing air into the building, and importantly, it does not necessarily cool the air, instead relying on air flow to provide a cooling effect. This use of the malqaf or wind catcher has been employed in this manner for thousands of years in most Middle East countries. A schematic diagram of the badgier system is shown in Figure 3.

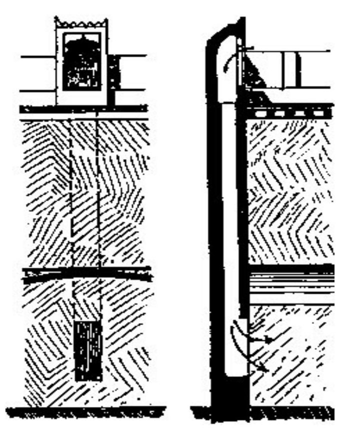


Figure 3: Badgier System

The badgier-sirdab system was a cheap, environmentally friendly and energy saving solution to create an acceptable climate inside Iraqi houses - not an easy endeavor with outside temperatures of over 50°C during the summer.

2.2 Present Iraqi Housing

Housing design in Iraq has moved away from the traditional thick-walled structure with small windows built around a courtyard with integrated environmental management systems. The walls of modern houses are constructed of either 15 cm brick or 20 cm hollow concrete blocks with or without thermal insulation. Roofs are flat, sacrificing key passive functions of more traditional sloped roofs, and constructed of 150 mm thick pre-cast concrete slab with waterproofing membranes, with and without insulation materials. Windows are typically aluminum frame, with one layer of glazing. Such dwellings are virtually uninhabitable in summers without energy-intensive air conditioning / cooling. This type of construction was enabled in the past by cheap energy and centralized utility-scale generation and distribution systems. Modern builders have sacrificed traditional high-performance construction based on the assumption of inexpensive, readily available power.

2.3 Today’s Challenge

Recent years have underscored the need for energy efficient housing, as Iraq remains plagued by power shortages that affect most Iraqi citizens. The greatest challenge to designing energy-efficient housing in Babylon is related to high cooling loads resulting from the severe and harsh summer.

3.0 APPROACH TO A ZERO-ENERGY IRAQI HOME

To develop an energy-independent home, one must consider three primary matters simultaneously. First, one must specify passive systems to limit demand, which involves sizing, siting and building techniques that optimize energy efficiency to limit energy consumption as much as possible. Second, one must use energy efficient equipment and systems. After demands are minimized, one must finally provide for on-site energy generation using solar hot water, solar photovoltaic (PV) and wind turbine generation for hot water, space cooling and heating, pumps, lighting and appliances.

3.1 Passive Systems to Limit Demand

The first steps of house design include selecting the optimal form and orientation of the house for a given site and specification of solutions to address variables that significantly influence energy demand and enable solar

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energy solar energy, utilization. These variables include window area; window thermal and optical characteristics; area and orientation for solar thermal collectors and PV modules; thermal storage; HVAC system variables, and control strategies. The house should be oriented along an east-west axis to be more efficient for both winter heating and summer cooling. Passive solar heating design relies on a south facing exposure of transparent material (glass, plastic) to allow solar energy to enter; and a material to absorb and store the heat (or cool) for later use. Passive cooling relies on natural heat-sinks to remove heat from the building. Badgir-sirdab and shenashil features should be considered. Thermal mass, proper insulation material and proper windows, doors and shading systems should be leveraged to the greatest utility.

3.2 Energy Efficient Equipment and Systems

Energy efficient equipment and systems should be specified that minimize energy demand. Use efficient thermosyphon solar water heaters for domestic hot water consumption, efficient air heating system for the short season winter heating, and solar thermal absorption system or evaporative coolers for summer house cooling. High efficiency lighting can be either fluorescent or light emitting diode (LED) applications in addition to daylighting techniques. Ultra efficient appliances - refrigerators, freezers and others – are available on the market today. The size of the renewable electricity generation system will be in direct proportion to the energy efficiency of equipment and systems.

3.3 Renewable Energy Generation

Solar thermal applications and renewable electricity generation, including solar and wind, depending upon the local conditions, should be designed using standard design guidelines or readily available and reliable computer modeling programs.

3.0 CRITICAL PASSIVE DESIGN FEATURES

To achieve a zero energy home, several design features should be adapted, inlcuding practical use of interior space, less exterior walls and windows, best choice of house orientation, passive heating and cooling techniques, walls and roof insulation, efficient appliances, high efficiency lighting, well design of house water piping and air ducts.

A passive solar energy system is designed to collect, store, and distribute solar energy without the aid of mechanical or electrical devices. Passive solar design can make a home more comfortable in every season. The winter sun can warm a home´s interior, while simple shading and thermal mass strategies can prevent summer overheating. Passive solar design is based on the following five principles that optimize the use of solar energy for heating and cooling of a living space: building orientation towards true south, energy efficient windows, calculated roof overhangs, large thermal mass for energy storage and suitable walls and roof insulation [4-7].

3.1 Passive solar heating

In sunny, clear climates like Babylon, use of passive solar heating and building orientation techniques - in combination with proper insulation in roof, walls and windows - are critical for managing heat in buildings. Two elements are needed in all passive solar heating designs: a south facing exposure of transparent material (glass, plastic) to allow solar energy to enter; and a medium to store the solar radiation for later use [7,8]. Passive heating can be accomplished with direct, indirect and isolated solar gain.

3.2 Passive cooling

Passive cooling is not a new technology but a resurgence of ancient, time proven methods that have used to manage indoor temperatures of structures. Passive cooling systems rely on natural heat-sinks to maximize the efficiency of the building envelope by deriving cooling directly from evaporation, convection, and radiation without using intermediate electrical or mechanical devices.

Passive cooling design minimizes heat gain from solar radiation, and internal heat gains from appliances and occupants. Passive cooling is accomplished by maximizing airflow through the home and utilizing overhangs and trees for shade. The most effective method of cooling a building is to shade windows, walls and roof of building from direct solar radiation. Heavily insulated walls and roofs need less shading. Three methods are used in passive cooling. These are convective cooling methods, radiative cooling methods and evaporative cooling methods. Convective cooling methods use the prevailing winds and natural, gravity-induced convection to ventilate a house at the appropriate times of the day. Figure 4 shows a solar chimney.

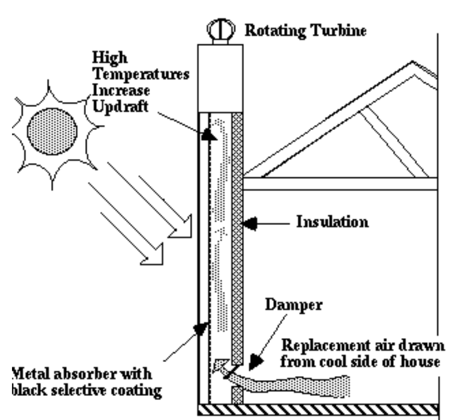

Figure 4: Solar Chimney

Radiative cooling methods rely either reflecting the solar radiation or on exterior water wall and roof pond systems to reradiate heat to cool interior spaces. Evaporative cooling methods rely on the high heat of vaporization of water to cool the air. One method is to drive the outdoor air through a cooling pad. Other strategies such as earth tubes and/or cool towers use the same principles but utilize natural systems for air drivers and distribution.

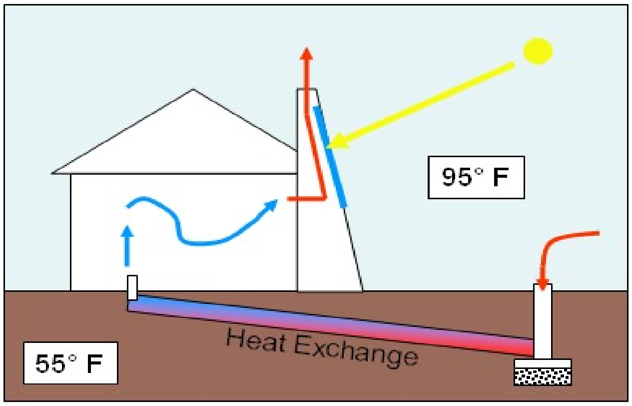

Figure 5: Earth Tunnel System

To reduce the effect of heat, efficient windows, insulation in roof and walls and methods of reducing infiltration should be used. Natural ventilation, shading, courtyard effect, wind tower, earth air tunnel, white roof, roof spray, roof pond and evaporative cooling can all be used. [7-19]. Figure 5 illustrates an earth tunnel system.

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