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THE IMPACT OF RESIDENTIAL BUILDING'S DESIGN ON THE ENERGY CONSUMPTION IN HOT DESERT CLIMATE (BAGHDAD CITY AS AN EXAMPLE)

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Abstract: Residential Buildings are responsible for a large portion of energy consumption in cities. The study of The Impact of Residential Building's Design on the energy consumption in hot desert climate requires careful examination and evaluating the validity of the commonly known assumptions and for quantifying the effects of building design on energy consumption. This research problem is the effect of residential building design on the energy consumption in hot Deseret climate for Baghdad city as an example. In this study several options for residential building forms, area, number of stories, and walls materials were selected for the assessment of energy consumption. Software simulation was to estimate an energy performance model for assessing various energy conservation measures pertinent to the building design. Percentage change was calculated and compared accordingly for each case. Results demonstrate that shapes with less surface area achieved better results. Also for wall materials the reduction reached to 50% for Thermostone wall for the same building form and area. The area of building and number of stories contributes on energy consumption too. Building with less area provides better results. Also buildings with two stories provide total energy consumption for average square meter less than on story building.

Keywords: Building shape, energy consumption, simulation, desert climate buildings..

INTRODUCTION

Buildings are responsible for a large portion of energy consumption that are of the main approaches to mitigate climate change and reduce C02 emissions besides its positive implications on reducing pollution, improving health and economy. Studies around the world have investigated and offered different methods in Building form, orientation, shading, insulation; thermal mass and density of the urban pattern were some of the commonly used techniques to reduce the energy consumption. However the impact of residential building design (building forms, area, form, area, number of stories, and walls materials) on the energy consumption in hot Deseret climate and for Baghdad city was not given enough consideration.

Recent studies

Many recent studies examine the relationships between building design, form, orientation, shading, insulation; thermal mass and urban fabric on energy consumption. (Hachem *et al*., 2011) studied the effect of different forms of singular and clustering buildings on solar gain for it. (Kämpf & Robinson, 2010a; 2010b) Accomplished an optimization method for the building and urban geometric forms to reduce the consumption of solar gain on the building envelope. (Depecker *et al*., 2001) studied the effect of building form on energy consumption where energy consumption for heating was related to the building form through a shape coefficient that related external surface area to the inner volume. It was more appropriate to cold weathers with medium or short periods of sunshine.(Yi & Malkawi, 2009) established a method for optimizing building form based on heating and cooling energy consumption using genetic algorithm with a goal of minimizing heat transfer between indoor and outdoor. A theoretical building with no windows was used, in which day lighting, artificial lighting Energy and the effect of transmitted solar radiation was not addressed in the optimization procedure (El-Deeb *et al*., 2012) Studied the effect of building form and urban pattern on the energy consumption of air-conditioned buildings in different desert environments. A simulation by Energy-Plus software to different shapes for buildings in three cities Jeddah, Cairo and Alexandria. Results demonstrate that common desert building forms and urban patterns do not always yield the expected reduction of energy consumption. Zina (2015) studied the main type of construction system in residential buildings in Baghdad. Tested was through dynamic simulation using Design Builder software to study its thermal performance. A parametric study was carried out for several cases in an attempt to improve and optimize the building fabric. It was found that adding insulation to both the external walls and roof had a very positive impact on energy efficiency. It was also concluded that the use of shading and avoiding east and west orientations also helped in reducing cooling demands. Regarding fenestration results showed that using several narrow windows to replace the more common large windows also had appositive impact on achieving energy efficiency.

Iraq climate

Iraq is situated between latitudes 29-37°N. Its capital Baghdad is at 33° 19′ N, 44° 25′ E. It is part of the Middle East and North Africa. Its climate is classified as hot and dry in summer, cold and humid in winter, (Al-Jawadi, 1986) and can be divided into three climatic areas. Aired/ desert for south and west of Iraq, semiarid for middle and part of south of Iraq, Mediterranean climate for north of Iraq. As for Baghdad city the climate is semiarid (Al-Ansari, 2013). Summer peak temperatures reach higher than 50°C when the average max temperatures in summer reach to 45°C, and average temperature exceed 30°C for 5 months in Bagdad (Alsammarae, 2005).

Energy consumption in Residential building

Residential building required energy to operate daily purpose like lighting, heating and cooling, and other processes and activities of daily operation. In Iraq most of the energy demand went for residential building. In Baghdad as an example residential buildings are responsible for 48% of the total energy consumption, 29% of the consumption is by industrial buildings, 13% by office buildings, 6% commercial buildings and agricultural buildings form 4% of the total energy consumption (Alsammarae, 2005) .Houses in Baghdad consummated 69% of the annual energy use for is used for cooling, with 26% for heating. These are very large numbers if compared with the energy demand required for lighting and appliances and other acquirements, which contribute to 5% only of the annual energy demand for houses. (Abbood and Rahman, 2015).

Residential Building Types in Iraq

Another variable of energy consumption in Iraq is the housing types. Different types of housing correspond to different properties, such as differences shape of buildings, heights, materials of construction, and differences in buildings orientation. The effect of housing types results in different of energy consumption for each type. A survey was made by Zina (2015) showing that the most common plot area is between 100–400 m² and the majority of houses had two stories, and a major material used for walls is brick wall and concrete for ceiling.

Research objectives

The main objective of this research is to contribute to the understanding of the impact of Residential building's Design on the energy consumption in hot desert climate and for Baghdad city as an example. This goal can be achieved through:

1- Investigating the using of various options of building design in energy consumption.

2- Identifying the optimum buildings design in energy consumption.

Methodology

Research studied many building forms, heights, wall materials alternatives. Simulation was made using Rivet and Ecotect software 2011 using an interpolated weather data file from the Energy plus website. The shapes of building included basic building shape (Square, Rectangle, L-shape, U-shape and H-shape). These forms were tested in case of being freestanding (isolated), and for different building area in 100 square meters, 150 square meters, 200 square meters, and 400 square meters, and with different wall materials. They were tested two options of single story and two stories.

Analysis was performed for building form and areas and wall materials and building stories. The effect of building form was addressed by comparing the energy consumption of the selected form with that of a base case of a free standing "square" shaped building. Percentage change was calculated and compared accordingly. The effect of building area was addressed by comparing the energy consumption of the selected area with that of a base case of 100 square meters building. Percentage change was calculated and compared accordingly. The effect of different wall materials was analyzed by addressed by comparing the energy consumption of the selected materials with that of a base case of a brick wall building. Percentage change was calculated and compared accordingly. The effect of building number of story was addressed by comparing the energy consumption of the selected height with that of a base case of a single story shaped building. Percentage change was calculated and compared accordingly.

RESULTS AND DISCUSSIONS

The results shows that the effect of building shapes, area, heights, wall materials on energy consumption is different in each the tested case.

The effect of buildings shape on energy consumption

The tested shapes of building include basic building shape in Iraq with the same area 100m^2 (Square, Rectangle, Rectangular with courtyard, L-shape, U-shape and H-shape) as shows in **Fig. 1** the result shows in **Table 1**.

As shown in **Table 1**, shapes with less surface area provided better results. The square shape consumed less energy. The other shapes provided very little energy savings in comparison with the square. Shape with large surfaces areas such as H and U increase consumption by 33% to 32%, as compare to the maximum month energy consumption to the square shaped building.

Respectively courtyard rectangular shape increased energy consumption by 27.6 %, and rectangular shape increased energy consumption by 15 %. Compare to the maximum month energy consumption to the square shaped building. **Figure 2** shows the maximum energy consumption for each shape of building.

The effect of buildings floor area on energy consumption

The tested floor area of building included 100 m^2, 150 m^2, and 200m^2 for comparison purpose 100 m^2 was selected. The result showing in **Table 2**, building with less area provides better results. For a building with an area 100 m^2 the energy consumption is less than 150 m^2 in about 35%. And for a building with an area 150 m^2 the energy consumption is less than 200 m^2 in about 20%. **Figure 3** show the maximum energy consumption for each floor area of building.

The effect of number of buildings stories on energy consumption

The verified area of building included single story and two story building for comparison purpose single story building was selected. Different buildings areas 100m^2, 150m^2, and 200m^2 were tested, and square shape building was selected to comparison and the wall was from brick thickness 0.25 m and the ceiling from concrete thickness 0.22 m. The result is showing in **Table 3**.

Table 1. Energy consumption for cooling in Wh. for differrent building shapes.

E*	Square	Rectan-gular	R*	L-shape	U-shape	H-shape
Max. Month	195901	2302111	2702721	2532302	2841796	2978564
Max. Hour	8557	9747	11284	10635	11831	12359
Total	8683755	10144081	11863209	11130187	12461722	13050599
Per. M2	86838	100816	119559	111066	124617	129857

E* = Energy consumption for cooling in Wh, R* = Rectangular with court yard.

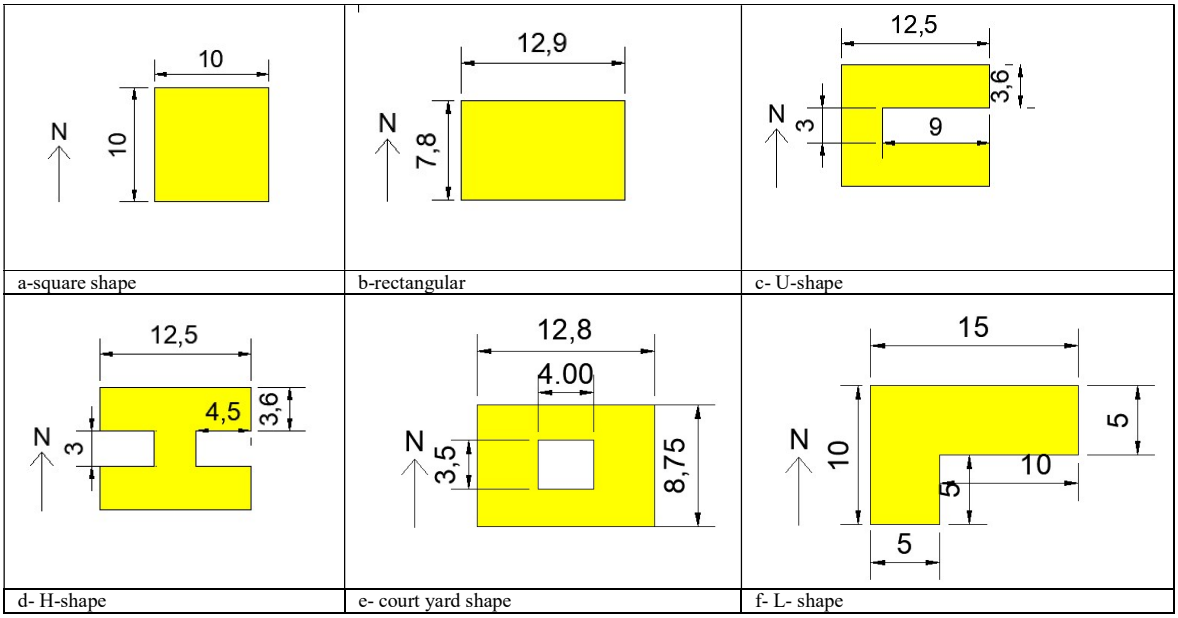

Fig. 1 Basic building shape.

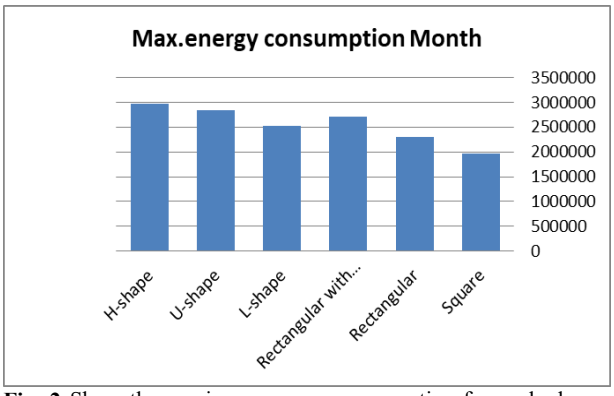

Fig. 2 Show the maximum energy consumption for each shape of building.

Table 2. the maximum energy consumption for each floor area of building.

Energy consumption for cooling in W	100 m²	150 m²	200 m²
Max. Month	47220.5	67165	85931.8
Max. Hour	2366.0	3554.8	4583.8

Table 3. Energy consumption for cooling in Wh. for number of buildings stories.

Energy consumption for cooling in Wh		100 m²	150 m²	200 m²
Max. Month	Single	1959016	3015055	3721002
	Two	3297753	5533204	6818578
Max. Hour	Single	8557	12911	16057
	Two	14765	24232	30151
Total	Single	8683755	13359979	16521241
	Two	14736409	24646416	30422808
Average Per. M2	Single	86838	89029	82514
	Two	73682	82120	75972

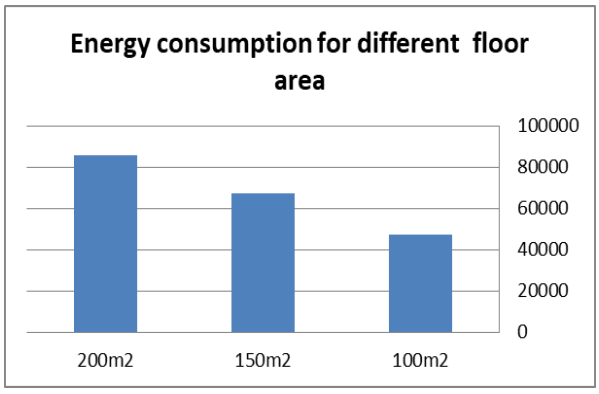

Fig. 3 Show the maximum energy consumption for different floor area of building.

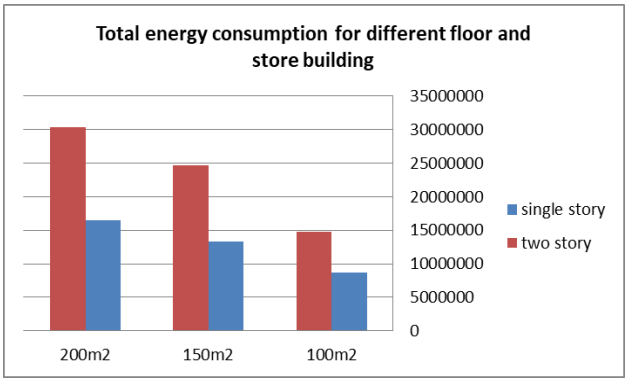

Fig. 4 Show the total energy consumption for different floor area and story of building.

Table 4. Energy consumption for cooling in Wh.

Energy consumption for cooling in Wh	Wall /Brick	Wall/Thermo stone	Wall/Double Brick cavity
Max. Month	1959016	987022	998715
Max. Hour	8557	3979	4512
Total	8683755	4355113	4493039
Per. M2	86838	43551	44930

As shown in **Table 3** building with single story provide energy consumption in total consumption between 40-45% as compared to two stories for building, and the average energy consumption for average square meter for single story is more than two stories. **Figure 4** shows the total energy consumption for different floor area and story of building.

The effect of buildings wall materials on energy consumption

Four common local materials for wall construction were tested (brick wall 0.24 m, Thermostone 0.20 m, double brick cavity wall 0.34 m), and brick wall was choice for a comparison. The shape of building was square and for 100 m^2. The result showed in **Table 4**.

As shown in **Table 4** building with Thermostone wall provide energy consumption maximum in month about 50% so as for double brick cavity wall. In order to total building with Thermostone wall provide energy consumption in about 50%. When provide energy consumption for double brick cavity wall in about 48%. As compare to brick wall construction.

CONCLUSION

The most significant factor that effect on energy consumption for building in hot desert climate between all tested samples was the wall materials the reduction reached to 50% for Thermostone wall for the same building form and area. As compare to brick wall construction.

Shape of building also effected on energy consumption. Shapes with less surface area achieved better results. The square shaped building form provides excellent performance where savings reached approximately to 30% as compare to the other shapes.

The area of building contributes on energy consumption too. Building with less area provides better results. With energy consumption reached more than 50% for doubling the building area. And buildings number of story provide energy consumption per square meter in about 15% for two story 100 m^2 building, and about 8% for two story 150,200 m^2 building. Also buildings with two stories provide total energy consumption for average square meter less than on story building.

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