Guidelines for Low-Cost, Energy-Efficient House in Iraq

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Abstract: The goal of this study is to determine specific guidelines for Iraqi architects to contribute to the design and composition of energy-efficient housing units within the limits of a normal budget, locally available materials and technologies. These units can provide comfort despite the current energy situation in Iraq. The study is based on a computer simulation for a reference building in Baghdad, which has been selected according to the urban conditions, building legislations, housing market and statistics. The final results displayed the main recommendations and the possibility to achieve up to 50% energy reduction with a pay-back period not exceeding two years in some cases. There are some measures that have big energy saving potential. Yet, some of the measures may require big investment or have some bad environmental impacts. Some other good measures are already being implemented.

Key words: Iraq, housing, energy-efficiency, cost, simulation, optimization, material, heating and cooling.

1. Introduction

1.1 City Study

The Republic of Iraq is a country situated in west Asia with a total area of 434,128 km² and an estimated population of 32,665,000. In 2009, 66% of Iraqi citizens were living in cities and urban areas [1]. Baghdad is the capital and the largest city hosting an estimated population of 8 million [2].

1.2 Housing and Energy Problems

The provision of housing represents one of the largest challenges in Baghdad and in Iraq as a whole. The estimated housing need in Iraq over the 10-year period from 2006 to 2016 is about 1.27 million units in urban areas [3]. By 2020, population of Iraq is expected to reach 40 million inhabitants [4]. In Iraq, 27% of households do not have shelter, about 30% of households in Iraq experience at least two slum-like conditions according to a survey conducted by UN-Habitat (United Nations Human Settlements

Programme), and about 13 % experience three or more slum-like conditions [3].

Due to decades of war and sanctions, Iraq generates about 50% of its demand with average 8,000 megawatts generated power compared to 15,000 megawatt power demand¹. Iraqis pay extra fees to private generators and the electricity price from these generators is relatively high with 8-hour daily supply power of one kilowatts (costs about 50 USD per month)².

1.3 Baghdad Climate

According to Köppen Geiger map of world climate, Baghdad lies in the hot arid desert region Bwh (Bw: desert climate, h: low-latitude climate (average annual temperature above 18 °C)) [5]. Due to the lack of up to date weather data in Baghdad, weather data was obtained from Autodesk® Green Building Studio web-based tool which provides weather data for virtual stations in areas where actual data are missing. In Baghdad, dry bulb temperature ranges between a maximum of 48 °C in summer days and a minimum

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¹Electricity Factsheet, IAU (Inter Agency Information and Analysis Unit), Iraq, 2010.

²S. Rashid, local market analysis, 2012.

temperature blow 0 °C in the coldest winter nights [6]. Fig. 1 shows the hourly temperature profile and comfort-thermal neutrality.

Baghdad has a clear sky with average cloud range less than 30% and the relative humidity is low especially in summer [7]. The prevailing wind comes from north-west which sometimes brings sand storms from the western desert. However, there is also the south-eastern wind locally known as Sharji-Arabic for eastern. The wind speed is between 1~2 m/s except when sand storms blow [6].

2. Focus Building

To deal with missing information of energy demand, a computer simulation using ECOTECT® software

was performed to calculate the energy demand for a “reference building”. As a reference building, a single family house was selected. The selection was based on analyzing building legislations, urban situation, building material, and market and construction industry. The house is designed for a family with 6~7 members with five bedrooms, a kitchen, living room, guest room, two bathrooms and three small water closets. It also has a garage, a garden and a small courtyard. The house is attached with south-north orientation and main facade facing south.

Looking at the construction material and details, the house is to be built with 24-cm brick load bearing walls with gypsum plaster as interior finish and stone-cladding as exterior finish. The roof is 15-cm

Fig. 1 Reference building floor plans.

reinforced concrete slab with insulation, water protection, sand and concrete tiles on top. Windows used are single glazed with aluminum frames and protection grilles. The heating and cooling load for the building were 43.68 kWh/m²a and 98.09 kWh/m²a respectively with maximum heating power of 9,608 W at 08:00 on January 13th and max cooling power of 16,989 W at 15:00 on September 16th³.

3. Building Optimisation

A look at the psychrometric chart (Fig. 2) shows some of the measures to be implemented to optimise the building such as thermal mass, shading and passive solar gains. However, this section will deal only with the reduction of loads without including HVAC (heating, ventilation and air conditioning system).

3.1 Air Tightness

In the simulation of the reference building, air change rate (indicating air tightness) was set to 2.0 air change per hour. Ventilation counts for 37.4% of the total losses and 12.1% of the heat gains. By improving windows' air tightness and the way they are fixed on the wall, there's a significant reduction especially in the heating load. Better air tightness is also helpful to reduce the effect of sand storms.

3.2 Building Material

An array of possible building materials were used to reach the optimum choice, and material changes include the walls, roofs and finishing material with or without insulation. Material choice is based on the available material on the market. For exterior walls (facade walls), four different wall types were tested: brick wall (24 cm thick) with cement rendering as exterior finishing, brick wall (24 cm) with stone cladding (5 cm gap between the stone and the brick either left as air-gap or filled with glass-wool) and

ICF (insulated concrete form) which consists of a 12 cm concrete filling the gap between two layers of polystyrene with thickness of 6 cm each and cement panel as exterior finish. The roof construction includes the slab (concrete or brick arches), damp proof layers, sand (for the slope), tiles and sometimes insulation layer [8]. Table 1 shows the thermal loads for the alternatives.

The most efficient material alternative was the ICF structure with double glazed windows [8]. However, the ICF structure is a concrete construction which is highly energy intensive in the production phase which may make it not the best alternative if the whole process is taken into account. It is also not very widespread because it is relatively new in the market and there is only one factory in Iraq.

3.3 Windows

Single- and double-glazed windows were tested as window types. Furthermore, windows size and position were also subject to changes, which were based on research papers conducted mainly by Dr. Miqdad Aljawadi about the effect window position, shape and size in providing shade in summer. In the reference building, the window sizes are large reflecting the general trend. Windows of the house are facing different orientations, the main facade faces south, while the backyard windows face north and west and, in the courtyard, west oriented windows are used. South facing windows function better if horizontal because the sun angle in summer is very high. In case of vertical windows, it is recommended to divide the height into smaller windows [9].

The windows used in the south facade are big with 2.4 m in width and 1.2 m in height. It is proposed to use smaller windows, 2 m in width and 1.1 m in height. Generally, when windows are facing north, vertical windows are preferred and the use of several smaller windows is better than a single large one [9]. However, in the house, north facing windows are only the small bathroom windows. West facing windows

³ECOTECT® Analysis, building simulation by author using ECOTECT® software, 2012.

Fig. 2 Psychrometric chart showing comfort limits and passive design measures.

Table 1 Heating and cooling loads for different wall and roof types.

Wall	Roof	Window	Air change rate (air change/h)	Thermal load (kW/m ² h)	
				Heating	Cooling
Brick wall 24 cm + render	Reinforced concrete	Single glazed	2.0	44.68	100.09
			0.5	25.27	82.52
		Double glazed	2.0	38.91	87.63
			0.5	19.38	70.43
Brick wall 24 cm + stone cladding	Reinforced concrete	Single glazed	2.0	43.68	98.09
			0.5	24.09	80.66
		Double glazed	2.0	37.69	85.74
			0.5	18.05	68.84
	Jack arch brick	Single glazed	2.0	45.96	102.68
			0.5	26.26	85.48
		Double Glazed	2.0	40.04	90.37
			0.5	20.10	73.67
Brick wall 24 cm + insulation + stone cladding	Reinforced concrete	Single glazed	2.0	43.08	97.59
			0.5	23.52	80.48
		Double glazed	2.0	36.98	85.70
			0.5	17.01	69.81
ICF	Reinforced concrete	Single glazed	2.0	35.24	83.77
			0.5	16.24	66.23
		Double glazed	2.0	29.25	71.45
			0.5	16.45	64.58

Table 2 Heating and cooling load building material and optimized windows.

Wall	Roof	Window	Air change rate (air change/h)	Thermal load (KW/m ² h)	
				Heating	Cooling
Brick wall 24 cm + stone cladding	Reinforced concrete	Single	2.0	41.55	96.84
		Double	0.5	17.06	69.01
	Jack arch brick	Single	2.0	44.12	98.60
		Double	0.5	18.52	72.96
Brick wall 24 cm + insulation + stone cladding	Reinforced concrete	Single	2.0	41.45	93.35
		Double	0.5	16.04	68.42
ICF	Reinforced concrete	Single	2.0	34.10	79.86
		Double	0.5	9.50	53.74
Brick wall 36 cm + stone cladding	Reinforced concrete	Single	2.0	41.48	96.94
		Double	0.5	12.31	61.81

Fig. 3 Window grill/shading louver.

are also preferred to be horizontal, therefore similar windows' dimensions were proposed for the windows facing the courtyard and the backyard.

As can be seen in Table 2, the use of single- and double-glazing was also tested, and the results show that using double glazed windows has influence with similar percentages on both heating and cooling load. Windows are placed on the interior edge of the opening, in this case, the lintel and edges provide shading for the window, thus, reduces the direct solar gains [10].

3.4 Shading Devices

Shading devices could be fixed on overhangs, louvers or operable sunshades. Overhangs already exist in the reference building design but not for all windows. Operable shades might not be preferred aesthetically. For the rest of windows, it is possible to use an array of small scale louvers by redesigning the

windows' grilles which are typically used for security purposes.

The louvers have a shading coefficient of 100% in summer and 32% in winter [11]. However, the added louvers do not provide a remarkable improvement on energy demand in this case because most of the windows in the reference building are already shaded by other masses. Fig. 3 shows a detail of the proposed window grill⁴.

3.5 Other Measures

There are additional measures to reduce the energy demand (especially cooling), the effect of these measures might not be high but, together with other measures, there could be a significant improvement. These measures include the use of light colors, trees, vegetation and changes in the building's zones.

4. Scenarios

In this part, different scenarios for heating and cooling systems will be developed. A comparison between the scenarios will be implemented based on simplified economic estimations to reach the optimum system: the economic balance will include construction costs, HVAC cost, operation and other costs.

4.1 Reference Building

As noted above, the heating and cooling loads for the reference building are 43.68 kWh/m²a and 98.09

⁴Ibid 3.

kWh/m²a. Free-running building simulation showed that about 60% of the hours exceed adaptive comfort limit which includes a human factor assuming that people would change behavior when temperature exceeds the limits to restore comfort based on Humphreys and Nicol (1998) model, therefore having an adaptive building here is not possible and the building has to be air conditioned.

Sizing the AC (air conditioner) split units is based on the simulation results for maximum heating and cooling, the size will be displayed in ton of refrigeration (3.52 kW) for each room and assuming a coefficient of performance of about 2.6, and the energy demand will be calculated by converting the power needed into amperage, knowing that the electricity grid in Iraq has a voltage of 220 v. Table 3 shows a rough estimation for the investment in constructing the reference building (including the AC units).

As noted above, the energy cost is calculated based on the maximum power which is how electricity from private generators is priced. Price of electricity from private-owned neighborhood generators is amperage-based, for instance, a daily supply of eight hours with five amperes current costs 50 USD per month, 10 amperes would cost 100 USD and so on⁵. The reference building in this case would consume about 7,965 W or 36 amp only for cooling and 4,451 W or 20 amp for heating in winter excluding other uses. In a simplified calculation, assuming that electricity from private generator is needed 16 hours a day, the monthly price will be 20 USD per ampere, translated to an annual cost of 5,520 USD only for providing comfort.

4.2 Optimized Brick Walls: 36 cm

In this building, thicker exterior walls are used with double glazed windows and better air tightness. The living room will be smaller because of the partition that isolates the stair case from the room. The use of

36 cm thick walls will be more cost intensive in terms of material as well as labor. In this case, the cost of the structure is estimated to be 240 USD/m², the double glazed windows have extra cost of about 30 USD/m². Moreover, the grilles/shading louvers will have a cost of 50 USD/m².

For cooling, it is possible to use split-unit AC or evaporative coolers while AC or electric or oil heaters can be used in winter for heating. As show in Table 3, the construction cost was roughly estimated for this scenario, this time, including the cost of air conditioners or evaporative coolers and oil.

In this scenario, the construction cost when AC units and evaporative coolers are used goes up to 123,913.25 USD and 122,783.25 USD, respectively, and the annual energy cost goes down to 2,700 USD when split-unit ACs are used and 1,800 USD with evaporative cooler and electric heater, and 620 USD with evaporative cooler and oil heater.

4.3 Optimized ICF Walls

ICF walls would have no difference in thickness compared to reference building, but better air tightness and double glazed windows and the wall layers perform better. Compared to “conventional” brick construction, the cost of ICF structure is lower thanks to the lower labor cost and the market preference for brick. The total construction cost (including AC or evaporative cooler and electric heaters) would be slightly more with 10,8423.6 USD and 106,693.6 USD. In this case, the AC sizes are the same as the previous alternative, and the energy cost will be similar, which also applies for the evaporative cooler. The only exception is the heating cost. As the heating load is less, so are the heating hours, as a result, with oil heating, 263 L are needed which cost 13 USD if normal rates are applied and 780 USD if electricity is used for heating.

5. Results and Discussions

Based on the estimations of all three parameters

⁵Ibid 2.

Table 3 Construction costs in USD for reference building.

	Quantity	Unit	Cost (USD/unit)	Total cost (USD)
Structure	254.7	m ² f-a	180	45,846
Facade	41.53	m ²	25	1,038.25
Windows	33.1	m ²	50	1,655
Doors	16	Item	180	2,880
	1	Item	300	300
Floor finish	288	m ²	18	5,184
Plumbing	28	Plug	160	4,480
	1	-	-	2,000
Electrical	76	Plug	100	7,600
	1	-	-	3,000
Other	1		30,000	30,000
	2	Unit 0.5 t	250	500
	3	Unit 0.75 t	280	840
AC	2	Unit 1 t	310	620
	1	Unit 2 t	650	650
Total				106,593.25

* stands for Incl. 1,000 USD rough cost for ground water.

Fig. 4 Investment and operation cost for first and second years.

abovementioned, Fig. 4 displays the total investment and current energy cost from private generators. The figure shows that ICF alternative pays back within the first year considering the prices from the private generators. It is hard to define a longer period for investment because of the expected improvement in

electricity sector. Nevertheless, when the supply will be close to cover the demand, there are plans for new prices mechanism to strengthen the Ministry of Electricity.

6. Conclusions

By defining the points with the largest potential and

Table 4 Energy saving potential of different measures.

Measure	Energy saving		Cost*	Environmental impact
	Heating	Cooling		
Thermal Insulation	5%	5%	+5%	
Thicker Walls	30%	15%	+25%	
ICF	50%	20%	-10%	- energy in production - thermal mass discontinuity - concrete recycling
Air Tightness	35-40%	15-20%	-	air tightness
Double Glazing	20%	15%	+50%	+ comfort
Shading Devices**	-	5%	+50%	
Window Size	5%	5%	-30%	
Color (white)	-5%	5%	-	
Evaporative Cooler	-	50%	50%	+ urban heat island - water availability

*cost difference in comparison to normal costs for the single unit;

** stands for the use of window grills as shading louvers;

- stands for negative environmental impact;

+ stands for positive environmental impact.

choosing the optimum solution for the scenarios, it is possible to reduce the primary energy demand from 147.227 kWh/m²a to 76.97 kWh/m²a. Table 4 depicts a comparison between the different measures in terms of energy performance, cost and other environmental impacts to be taken into consideration.

By analyzing the reference building, some of the design strategies already used have a positive impact, e.g., building compactness, overhangs and roof insulation, and these measures can be further developed whereas some other design features can be modified and some other simple details can have a big impact. The final outcome when these measures are considered is distinctive but not bizarre.

The design measures and recommendations represent a working methodology which can be applied for designing different housing units with different requirements: these measures can also be implemented in renovating old building to improve comfort level. On the other hand, economic evaluation and comparison help the architect and developer in sharing the information with the client in understandable form and help in decision making.

The main challenge faced by this approach may be the unskilled labour and the cost, especially knowing that the loan for building a house does not exceed

25% of the total construction. Consequently, people look for the cheapest solution without asking for the better. Another problem which is more an urban problem is the regulation and the tendency to own single-family houses which are not the most efficient alternatives.

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