The effect of residential building façade design on energy consumption for hot desert climate

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Abstract: One of the most prominent parts of the building envelop that exposed to the external environment is the façade of building due to the pressure of environmental conditions as compare to the rest of building. Previous literatures had presented many researches in this field, but the study of the effect of the residential building façade design in reducing the energy consumption of buildings had not been adequately addressed for hot desert climate. The aim of this research is to determine the design characters for the façade of residential buildings. That includes wall materials, window to wall ratio, and the shape of windows, that reduce energy consumption in summer session. To achieve this goal, a typical type of two stories residential building had been adopted and tested by software simulation program to estimate the energy performance. The results showed that most efficient materials for the façade were the thermostone block with brick claddings. As for orientation the best results was for north elevation. And for window to wall ratio the best value was 20%.

1. Introduction
The problematic of energy demands rise globally, due to the climate change that faced all countries of the world, especially in hot aired cities [1]. One of the major consumers of energy in hot aired cities is the residential buildings [2]. The façade of building envelops play an important role in residential buildings energy consumption due to its daily confronted to environmental outdoor conditions. There were many previous literatures in this field. Shakila Pathirana, et, al, 2018 examined the effect of building orientation, window to wall ratio for different houses in tropical climate, on thermal comfort, day lighting, and airflow. The result showed that window to wall ratio and windows location into the wall had an effect on thermal comfort for all shapes of buildings [3]. While Ahmed S. Muhaisen, et, al. 2015 Studied the relationship between windows formation design and energy consumption for housing buildings, the research discovered that window orientation to the south increased energy consumption, and the higher window to wall ration leads to more consumption of energy in summer time, the material of window with lower U-value reduced the energy demand [4]. Also Katerina Tsikaloudaki, et, al. 2012 focused on the effect of window design, and properties on energy consumption for office building. For warm climate region in Europe. Many tested design of window types, orientation and materials. The results showed that also there was a need to larger window area to get natural lighting in office building but the energy consumption raised for cooling purpose [5]. Hassan, 2018 Studied the effect of residential building design on energy performance, a comparative were done between buildings shapes, floor area, stories of buildings, and wall materials. The results for wall materials
concluded that Thermostone provided better results as compared to other materials [1]. This research aims to discover the effect of façade design on energy consumption for residential buildings in hot desert climate.

2. Façade Design
There are many effective design characters for the residential building that affect energy performance. That includes wall materials, wall finishing, wall orientations, window to wall ratio, and the shape of windows. The main goals of façade design characters are to get comfort for the residence that mostly includes thermal comfort, good view to outside of the building. Protect form noise, good natural air ventilation, and minimize energy loads. The façade of building from another side deals with many sources of thermal loads from surrounding environment and sunlight. The thermal loads from sunlight can be divided into:

- The direct sun light,
- The reflected sun light from the near surfaces,
- The sky dome light.

Many strategies were adopted by the designers to minimize these thermal loads for the façade of buildings, like wall insulations, sun louvers, minimize window to wall ratio, but the study of these strategies for Baghdad city have not been adequately addressed.

3. Research Objective
The main objective of this research is to contribute to the study of the role of the residential building façade design on energy consumption for Baghdad hot desert climate. This goal can be achieved through several options for façade characters on energy performance:

- Investigate the use of different options of wall materials, and orientations.
- Examine various options of window to wall ratio.
- Examine various alternatives of window formations.

4. Methodology
Research studied different residential buildings wall materials, orientations, various options of window to wall ratio, and different alternatives of window formations. Simulation for cooling loads was made using software, Hourly analysis Program HAP4.9 software. The tested sample was 100 square meters residential buildings in Baghdad city, dimensions for external walls are (10 m x 10 m), two stories building. Building is congested from three sides which is the common types of buildings in Baghdad. The tested front façade wall material includes (brick wall with stone cladding, marble, and brick finishing) and (Thermostone block with stone cladding, marble, and brick finishing). The tested façade orientations elevation include (south, north, east, west, east, south east, south west, north east, and north west). These orientations were tested in case of being buildings attached with other residential buildings. The tested options of façade window to wall ratio included 20%, 30%, and 40%. Also tested were done to various alternatives of window formations (longitude and transverse formation windows). The maximum energy cooling loads were checked according to summer conditions for the period from April June till October. The effects of these options were addressed by comparing the energy consumption of the selected samples. Percentage change was calculated and compared accordingly.
The results showed the effect of different low-rise residential façade materials, orientations, window to wall ratio, and window formations on energy consumption. The tested façade materials included brick wall type (A) with (brick finishing A1, marble A2, and stone cladding A3), the second type Thermostone block (B) with (brick finishing B1, marble B2, and stone cladding B3) as showed in Fig 1. The results for it showed in Table 1 and Fig 2.

![Fig1. Façade wall samples types (Brick and Thermostone)](image)

| Energy consumption for cooling in Wh | Type A | Type B |
|------------------------------------|--------|--------|
|                                    | Brick Cladding | Marble cladding | Stone cladding | Brick Cladding | Marble cladding | Stone cladding |
| Max. Month                         | 200507 | 201891 | 196279 | 185234 | 185518 | 182998 |
| Max. Hour                          | 12849  | 12893  | 12288  | 12382  | 12393  | 12322  |
| Total                              | 1173425 | 1186098 | 1139589 | 1079143 | 1081258 | 1062441 |

![Fig2. Comparison of energy consumption for samples façade wall material](image)

The tested façade orientation elevation included (south, north, east, west, east, south east, south west, north east, and north west). The results for it showed in Table 2, and Fig 3.
The tested samples of window to wall ratio included three ratios (20%, 30%, and 40%). The results showed in Table 3 and Figure 4.

**Table 3. Comparison of energy consumption for samples window to wall ratio**

| Energy consumption for cooling in Wh | 20% | 30% | 40% |
|-------------------------------------|-----|-----|-----|
| Max. Month                          | 175941.4 | 207066.4 | 238180 |
| Max. Hour                           | 175941  | 207066  | 238180 |
| Total                               | 1047721.4 | 1237567.8 | 1427338.8 |
The comparative results for the window formations showed in Fig 5 (longitude and transverse formation windows) with window to wall ratio 15%, and the façade south orientation showed no differences in energy consumption for both formations.

5. Conclusion
The most efficient materials for the façade Thermostone block materials consumed less energy than brick wall material by almost 10% for all types of claddings. Also stone cladding consumed less energy than bricks claddings by 3 % and marble cladding by 4%. The façade orientation towards the north achieved the best results in saving energy consumption. It consumed less energy by 34% as compared to (West, South west, and South east) elevations, and 36% as compared to (North east, and North west).
The better window to wall ratio was 20% it consumed less energy by 27% as compared to WWR 40% and 16% as compared to WWR 30%.
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