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Investigating the Influence of Architectural Features on Thermal Behavior of Dominant Residential Structure Patterns in Tabriz Housing

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Abstract

This paper studies thermal behavior of dominant residential structure patterns in the city of *"Tabriz"* that has cold and dry climate. With this regard, thermal behavior of three typical residential structure patterns, including: traditional courtyard, row house, and high-rise building is studied to determine the most sustainable structure pattern that is capable of achieving the optimal energy consumption in Tabriz environment. For this purpose, it is necessary to study the thermal behavior of each type of structure patterns from different aspects. Therefore, the influences of several architectural features on energy consumption are investigated to provide designers, constructors, and consumers with useful measures for residential construction in the city of Tabriz. Thermal behavior of each type of structure patterns is simulated using *"Ecotect"* software. The simulation results are then analyzed using *"EnergyPlus"* software. Based on the results, in the city of Tabriz, the amount of energy required for heating residential structures under cold weather conditions are three times more than the amount needed for cooling them during hot season. Amongst all three types of dominant residential structure patterns in the city of Tabriz, the high-rise building pattern provides the best heating performance due to proper insulation and also for the maximum use of sunlight. On the other hand, the traditional courtyard pattern provides the best cooling performance due to the minimum heat exchange of its outer walls. The results also suggest that insulation with impact of 0.41 is the most significant variable parameter for residential constructions in Tabriz environment. Moreover, the precedence of other variable parameters is identified as: type of opening (0.32), construction materials (0.23), and orientation (0.04), respectively.

Keywords: Climate design, Energy consumption, Optimization, Tabriz housing, Thermal behavior

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Extended abstract

Introduction

Although the industrial sector has the largest amount of energy consumption, the share of residential sector is very high, yet. According to the global statistics released by the US Department of Energy in March 2010, energy is used in several segments of residential buildings. Amongst all segments, heating systems use the highest level of energy. Next levels of energy consumption relates to lightings and cooling systems, respectively. Since a large portion of energy is exploited by construction sector, the study of typology in the field of housing would be beneficial for professionals in terms of performance.

The aim of this study is to provide designers, constructors, and consumers with useful measures for high performance residential construction in the city of Tabriz. Consideration of such measures together with correct design strategies at the early stages of design and construction leads to optimization of energy consumption in residential sector. Thus, residential constructions would be sustainable in cold climate of the region with optimal energy consumption.

The first part of this paper, serves as a literature review, which studies research background and similar works in this field. In addition, based on the survey conducted in this part, the importance of the present work is defined. The second part of the paper describes the research methodology used in this paper. This part includes: climate description of the region, simulation method and scenarios related to thermal comfort in the city of Tabriz. In the third part, simulation results are analyzed and validated. This paper concludes by comparison of thermal behavior of three dominant residential structure patterns and the most sustainable structure pattern that is capable of achieving the optimal energy consumption in Tabriz environment. Moreover, the influences of several architectural design parameters on energy consumption in Tabriz housing are investigated.

A large number of research, imply parameters that are determined at the early stages of design have great effect on the energy consumption of the building. Research shows that 57% of energy-saving technical measures should be considered at the design stage and shows that residential structure design should be revised in a way that location of spaces in the plan follows the pattern of space occupation with respect of the solar cycle. They recommend the use of suitable shutters and glass and also suggest replacement of renewable energy.

This research is aligned with studies conducted by Hashemi et al. for the city of Ardabil that has similar climate condition to Tabriz. However, they have measured the amount of energy required for both heating and cooling with respect to the internal aspects of structures and also studied the effect of zoning and location of spaces in the plan, whereas the present study considers different parameters regarded to external aspects of residential structures that affect the thermal behavior of residential structures. Moreover, this research studies the thermal behavior of dominant residential structure patterns in the city of Tabriz to define significant features of architectural design to be considered under cold climate conditions as well as during hot season.

Materials and Methods

In this research thermal behavior of three dominant residential structure patterns, including traditional courtyard, row house, and high-rise building is studied to determine the most sustainable structure pattern that is capable of achieving the optimal energy consumption in Tabriz environment. For this purpose, the thermal behavior of each type of structure patterns is carefully studied from different aspects. With this regard, the influences of several architectural design parameters on energy consumption are investigated to provide designers, constructors, and consumers with useful measures for residential construction in the city of Tabriz. In this research, form of the structure and age of the building are selected as two independent parameters according to national thermal standards. In addition, four variable parameters namely orientation, construction materials, type of overlay, and

insulation are also measured. Effects of these parameters on energy consumption are studied for all three types of structure patterns considered in this research. Thermal behavior of each type of structure patterns is simulated using "Ecotect" software. The simulation results are then analyzed using "EnergyPlus" software. In addition, for validation of the results obtained through software simulation, a number of consumers' bills related to each structure pattern are collected as field impressions and comparison of energy consumption is conducted.

In order to determine the importance of each architectural feature for each type of structure, the criteria are weighted using AHP (Analytic Hierarchy Process) method. Hence, variable parameters together with independent parameters are organized in a matrix, and then multiple criteria are weighted using AHP method. Calculation of multiple weighted criteria results in precedence of parameters. Thus, the importance of each parameter in each pattern is determined.

Discussion of results

First, all three models are simulated and the amount of annual energy consumption for heating and cooling for each month is measured and the results are presented as bar charts accordingly. The results show that the highest level of energy required for heating is during November to April, which is due to the cold climate of Tabriz.

This amount exists on average and with a significant difference between a high-rise building with a row house and a courtyard house. Thus, considering the amount of energy required for heating regarded to square meters of the building, with a high difference, the high-rise pattern with lowest amount achieved the most optimal level of energy consumption. Among the other two patterns, the amount of energy consumption for heating in a courtyard house is slightly higher than in a row house. According to the results, the percentage of total amount of energy required for heating for each pattern is 43.2% for B.M.1, 42.8% for B.M.2, and 14% for B.M.3, respectively.

On the other hand, the results show that the highest level of energy required for cooling is during January to September, which is due to the short summer season in Tabriz.

Based on the obtained results, the traditional courtyard pattern has the advantage of proper climate design in that slight amount of energy is required for cooling. On the other hand, the high-rise building requires the highest amount of energy for cooling. Yet, this pattern provides the best heating performance due to proper insulation and also for the maximum use of sunlight. According to the results, the percentage of total amount of energy required for heating for each pattern is 21.8% for B.M.1, 34.7% for B.M.2, and 43.5% for B.M.3, respectively.

Based on calculations of the weighted parameters, significant architectural features are insulation (0.41), type of opening (0.32), construction materials (0.23), and orientation (0.04), respectively. In fact, consideration of these measures at the early stages of designing residential structures leads to optimal energy consumption in Tabriz environment.

Conclusions

In this paper, thermal behavior of three dominant residential structure patterns in Tabriz housing is studied to find out how different architectural features affect energy performance of residential structures. Overall, the outcomes of this study can be summarized as below:

1. The effect of independent parameters on the amount of energy required for heating and cooling is presented.
2. Numerical figures indicate that the amount of energy required for heating residential structures under cold weather conditions are three times more than the amount needed for cooling them during hot season.
3. Based on this study, the high-rise building pattern provides the best heating performance due to appropriate insulation and also for the maximum use of sunlight; however, this type of structure has

low performance in term of energy required for cooling, which is due to large openings in front design of this type of structure.

4. According to the analytical data, the row house pattern (the urban block model of 60% density) fails to compete with other residential structure patterns in terms of energy performance.
5. Generally, due to the cool weather condition in Tabriz during May to October, there is no need for any cooling or heating equipment for residential structures, and the weather conditions comply with the thermal comfort situation.
6. Simulations confirm the importance of selecting appropriate form of the structure as well as correct direction of the structure considering the maximum absorption of direct sunlight. Appropriate selection of these parameters improves the energy performance in terms of heating residential structures under cold weather condition in Tabriz.
7. Calculations performed using AHP method, determines that architectural features including insulation, type of opening, construction materials, and orientation have great impact on thermal behavior of residential structures in Tabriz housing. In fact, consideration of these influential features at the early stages of designing residential structures leads to optimal energy consumption in Tabriz environment.