Design an Optimum Pattern of Orientation in Residential Complexes by Analyzing the Level of Energy Consumption (Case Study: Maskan Mehr Complexes, Tehran, Iran)

Foad Faizia, Marzieh Noorani b, Abdolkarim Ghaedic, Mohammadjavad Mahdavinejad d

Abstract

The limitation of energy resources and the remarkable growth of their use in Iran compared with the universal average have doubled the necessity of optimizing energy consumption in this country. Considering that in recent years the housing and commercial sector has allocated the largest ratio (37%) of energy consumption to itself; designing the optimum pattern is one of the appropriate strategies. One of the primary ways to minimize energy consumption in residential buildings is design based on environmental conditions. In the recent years, the Maskan Mehr complexes were built by approach of affordable and suitable houses for all people in Iran. In this research by simulation the prevalent models of Maskan Mehr residential complexes and analysis the level of energy consumption in them via Ecotect software, existing examples are classified. The diverse types of Maskan Mehr are analyzed in four fields: shadows and overshadowing, solar radiation, lighting access simulation and thermal analysis. Afterwards regarding existing methods for minimum energy in building such as building orientation, location of translucent layers and the thermal inertial of layers based on the materials having been used in the buildings, the optimum pattern of orientation has been described. In conclusion, the results show that the given pattern should have following features:

- The lowest ratio of width to length along the North
- Having the maximum level of south-facing walls
- Design the most translucent layers in South, East, West and North side respectively
- Materials: Walls: Reverse Brick Veneer, Floors: ConcFlr _ Suspended, Ceilings: Suspended Concrete, Windows: Double Glazed_ Alum Frame, Doors: Foam Core_ Plywood

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1. INTRODUCTION

Considering the population growth in the world, the conservation of natural resources is one of the most important involvements for governments in today’s world. In the most countries, the residential energy consumption has allocated a large percentage of national energy consumption to itself [1]. In Iran, the portion of residential sector in energy consumption is 37% having the most portion compare with other sectors as shown in Fig 1. On the other hand, in the recent years the energy consumption in housing unit has increased in Iran and it has been doubled during 1998-2008 as shown in Fig 2. The diverse factors have impacted in residential energy consumption such as the population growth, economical performance, consumer taste, technological developments, and the building style [2].

In building domain, the architectural design based on climatic conditions and attention to energy saving is a great guideline for having the best efficiency in residential sector. These diverse roles have described guidelines for decreasing the energy consumption such as general roles about designing and implementation, the building envelope, mechanical installation and lighting [4].

2. Clarify the Problem

Recently, the Maskan Mehr complexes are being built by government in Iran for providing residence for various level of society. In this research we have studied the diverse types of Maskan Mehr complexes and they have been classified regarding energy efficiency levels and finally, according to the Tehran climate the optimum design has been presented.

Finding the best solutions to reduce energy consumption in residential complexes with respect to the climatic features and environmental impacts is the main aim of this paper.

As a first priority, a design should aim for a dwelling that uses the minimum amount of energy to run. This can be supported by, for example, applying conservation techniques and passive solar design principles [5]. Solar energy utilization by humans is prehistoric. Our ancestors took sensible advantage of solar energy from the rays of the sun. They understood the orientation of their living areas, the storage of solar energy, and how to distribute this thermal energy to other living spaces in their habitat [6].
Architectural design for buildings should be compatible with the climate as far as possible, so that the maximum use of favorable conditions is naturally gained. In addition, the building is protected against unfavorable climatic condition to reduce the amount of required energy to supply the heating and cooling of buildings and minimizing some of it through the natural way. Thus, the comfort condition is provided more favorable in architectural space. In addition to thermal insulation, the causative factors in use the natural energy in buildings are following:

- Building orientation
- Translucent layers
- The thermal inertia of layers

**Building orientation**

Building orientation towards the south in utilizing solar energy is very efficient. Proper orientation means that the South Translucent layers for gaining more of the sun radiant energy should be exposed to solar radiation in the most cold-days a year during 9 am-3 pm [4].

**Translucent layers**

The amount of Translucent Layers is very effective in heat transfer of buildings. Whatever the amount of Translucent Layers is less than the external surfaces, the less heat will be transferred to the outside. Despite supplying the suitable light for interior spaces, the adequate and appropriate amount of Translucent Layers cause that the heat transfer is reduced to the outside. Translucent Layers due to low thermal resistance compared to other parts of outer surfaces should not be located in the undesirable and cold fronts of buildings [4].

### 3. Research Methodology

In this paper the four diverse types of Maskan Mehr complexes are simulated and then by the Ecotect software the impact of buildings orientation, overall size and form of buildings, translucent layers and the thermal inertia of layers in shadows and overshadowing, the penetration of solar radiation to inside, lighting access for interior spaces and the level of thermal absorption are analyzed.

![Fig. 4. The research methodology for analyzing climate conditions](image-url)
Simulation process

3.1. Maskan Mehr residential complexes

In recent years, Maskan Mehr residential complexes are built in most cities in Iran by government with affordable and appropriate house for all people approach. These types of residential complexes have a great impact on building industry and construction in country. The four different types of Maskan Mehr complexes are selected based on its features having the main impact in energy consumption in buildings:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Materials</th>
<th>Orientation (angle between the main axis of building &amp; the North)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Walls</td>
<td>Floors</td>
</tr>
<tr>
<td>Building type -1-</td>
<td>Reverse Brick Veneer</td>
<td>Concrete Wall</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building type -2-</td>
<td>Double Brick Cavity Plaster</td>
<td>Insulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building type -3-</td>
<td>Reverse Brick Veneer R20</td>
<td>Tiles on Ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building type -4-</td>
<td>Brick Plaster</td>
<td>Insulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The features of four selected Maskan Mehr complexes [8]

3.2. Simulation program

Autodesk Ecotect Analysis is a building analysis software program that provides a number of tools for building design and analysis. It is geared towards environmentally conscious and green building design, making use of 3D models to visualize output [7].

Ecotect Analysis offers a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs. Online energy, water, and carbon-emission analysis capabilities integrate with tools that enable architects to visualize and simulate a building's performance within the context of its environment [8].

| Thermal performance | Calculate heating and cooling loads for models and analyze effects of occupancy, internal gains, infiltration, and equipment. |
| Solar radiation     | Visualize incident solar radiation on windows and surfaces, over any period. |
| Daylighting         | Calculate daylight factors and illuminance levels at any point in the model. |
| Shadows and reflections | Display the sun’s position and path relative to the model at any date, time, and location. |

Table 2. An example of a table [8]
3.3. Analyze process

- **Shadow analysis**
  Considering the significance of shadow and overshadowing in the orientation of complexes in site, in this research by simulation four types of Maskan Mehr residential complexes, the model of overshadowing of them during a specific day are analyzed. The selected day is winter solstice day in which the shadows of building are maximum. As shown in figure 5, the model of orientation has a direct impact in overshadowing in buildings. The maximum overshadowing has occurred in building type 4 during 11:00-14:00 p.m. because of its location along west-east axis. The maximum overshadowing for other buildings, are building type 2, 3, and 1 respectively.

![Building type (1)]() ![Building type (2)]()
![Building type (3)]() ![Building type (4)]()

Fig. 5. The shadow range of four types of residential buildings during 9:00 A.M. to 16:00 P.M. in winter solstice.

- **Solar radiation**
  The orientation of a building to sun position has a fundamental impact in energy absorption by solar radiation. By simulation how sunlight radiation occurs to the outside walls of a building during a day in winter, we have analyzed the optimal orientation of building for gaining the maximum radiation energy based on the sun position. Figure 6 show this subject for four selective building in which building having the maximum layers to south can absorb the maximum level of solar radiation.
Fig. 6. Solar access simulation for four types of residential buildings during 9:00 A.M. to 16:00 P.M. in winter solstice
As shown in building type 2 the orientation can help architects to design an optimal pattern based on solar radiation. Building type 2 has the ability to absorb direct solar radiation in two side but other types do not have this features. Regarding the results, the building type 4, 3 and 1 have the maximum solar absorption respectively because of the level of southern layers.

- Lighting Access Simulation

Penetration of natural light to the inside of building is one of the most important involvements for architects. In the residential building, windows do this duty. In the following lighting access simulation for four given types of Maskan Mehr residential complexes, it is obvious that day lighting penetration has limited depth based on the size of window in each side. Windows having been located in south side of the building have the maximum of lighting penetration because of its direct access to the sun light. As shown in figure 7, building type 2 has the optimal access to direct day lighting because of having the maximum level of translucent layers in southern front. Building type 4, 3 and 1 have the suitable access respectively. The important subject in these buildings is that the core of building type 1 has access to day light because of its H form but other types do not have this feature and the core of them is a dark area during day.

![Building type (1) and (2)](image1)
![Building type (3) and (4)](image2)

Fig. 7. The lighting access simulation for Building type (1) and (2) during 9:00 A.M. to 16:00 P.M. in winter solstice

Fig. 8. The lighting access simulation for Building type (3) and (4) during 9:00 A.M. to 16:00 P.M. in winter solstice
• Thermal Simulation and Analysis

As was mentioned in table 1, each of four building type has own specific materials. The material of walls, floors, ceilings, windows and doors for all four types of Maskan Mehr residential complexes have been described and regarding its characteristics the thermal conduction having been occurred in a year for each type which has been analyzed by Ecotect software. The red area in the following charts shows that the maximum level of passive gains breakdowns takes place in conduction part especially in cold seasons of year. Building type 4 has the most ratios in conduction part because of its own material having the minimum level of thermal resistance as shown in table 1. Buildings type 3, 2, and 1 have the most energy loss respectively and based on results in four charts the materials which have been used in building type 1 have the minimum level of thermal conductivity during a year.

![Fig. 9. Thermal simulation and analysis for four types of Building during 1 year.](image)

4. Conclusions

The orientation of a building is one of the most important factor by which the level of direct energy absorption is determined. In this paper, this subject has been analyzed by Ecotect software for four different types of residential buildings in Maskan Mehr complexes in Tehran, Iran. This analysis is divided to four major fields: shadows and overshadowing, solar radiation, lighting access and thermal simulation. Based on the results of simulation we can conclude that best choice of locating is orientation which takes place in building type 1 as shown in shadow and overshadowing analysis. In the solar radiation part, results show that building type 2 has the most efficiency in absorbing solar radiation energy. On the other hand, building with a large level of translucent layers such as windows in South and East can use more daylight penetration during a day like building type 2 in this research. In thermal analysis zone, the charts show that building type 1 with the material having been mentioned in 4.1. Part
has the less amount energy losing in its layers. Considering all results the optimal pattern of orientation should have the following features:

<table>
<thead>
<tr>
<th>Shadow and Overshadowing</th>
<th>Solar Radiation</th>
<th>Daylighting Access</th>
<th>Thermal Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building type 1</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Building type 2</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Building type 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building type 4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Optimal Pattern
- The lowest ratio of width to length along the North
- Having the maximum level of south-facing walls
- Design the most translucent layers in South, East, West and North side respectively

Material:
- Walls: Reverse Brick Veneer
- Floors: ConcFlr _ Suspended
- Ceilings: Suspended Concrete
- Windows: Double Glazed_ Alum Frame
- Doors: Foam Core_ Plywood

Table 3. The features of optimal pattern [8]

References