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Effect of Building Rotation on Thermal Energy Reduction and Total Solar Gain in Tehran Residential Buildings

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Abstract
Decreasing energy consumption is the one of the most important subject. Besides, in any building design, one employs simple techniques such as orientation, shading of windows, color, and vegetation among others, to create comfortable conditions. Accordingly, Total thermal and solar gain and the effective factors on them should be investigated and optimized. The objective of this research was to find out the impact of rotation on total thermal and solar gain which can lead us to achieve less energy-use in Iran. The software used for this research was Grasshopper and Lady Bug and Honey bee plugins. The typical plan without any environment effects was simulated and effect of rotation on total thermal and solar gain was analyzed. The results showed that using south radiation can be helped to decline total thermal and energy consumption. However, solar gain for east and west radiation was in maximum level.
Keywords: thermal energy, rotation, energy reduction, building simulation, residential building

1. Introduction 1

Buildings were designed regarding to environmental condition as temperature and humid capacity in Iran. By the growing use of mechanical equipment for providing human comfort, environmental pollutions and excessive fuel consumption were caused (Falakian and Falakian, 2013). The last decades have witnessed an unprecedented increase in buildings energy consumption and carbon dioxide emissions. Therefore, nowadays, renewable energies and decreasing energy consumption by passive design are highlighted in the whole world including Iran. Thermal energy consumption in buildings is caused by a combination of internal and external factors. Four major factors participate in determining the amount of energy required for cooling or heating a specific space and these factors are: climatic data, usage data, design data and finally materials data (Maher Ayyad and Olawale Fadeyi, 2011). Moreover, solar heat gain inside buildings is caused by solar radiation through transparent surfaces such as windows or skylights, or through opaque surfaces such as walls or roofs (Balcomb, 1992). The dramatic pace of developments in the building construction industry and the associated energy and environmental concerns have prompted researchers in exploring fenestration and shading systems for optimal control of solar gains and daylighting. Appropriate combination of overhangs and fins would be promising in attenuating the excessive solar radiation into buildings, and simulation tools play an important role in taking decision during early design phase that could help in improving the thermal performance of buildings (Ali & Ahmed, 2012).
Subsequently, building design parameters can be considered such as orientation, color of materials, shading of windows in order to achieve comfort situation. Accordingly, regarding to thermal comfort of occupants, orientation is founded as an important effective parameter (Odunfa et al, 2015: Morrissey et al, 2011). Climate factors like solar radiation and wind in region should be defined in building orientation (Falakian and Falakian, 2013: Nedhal et al, 2011). The orientation has enormous effect on absorbing day lighting, ventilation and air conditioning, shading and performance of solar envelope (Capeluto, 2003: Morrissey et al, 2011). Therefore, optimizing of building orientation can minimize energy consumption (Prasad A et al, 2017). As a general rule, the longest wall sections should be oriented toward the south (Mingfang, 2002). Hence, according to importance of decreasing thermal energy in buildings, in this research, the impact of orientation on total thermal and solar gain was examined and the best orientation of longest wall was explored.

1.1 Methodology

Building simulation is considered as a methodology for calculating total thermal of typical residential plan. To achieve this aim, Grasshopper was used for simulation which is a rhino plugin. The analysis is conducted in the sections as follow:

- Modeling a typical residential plan
- Total thermal energy simulating current plan based on Tehran climate zone
- rotating the plan in 30 degree sections and calculating its total thermal

• Discussion of the results

1.1.1 Modelling the typical plan

Typical residential plan is selected (as shown in Figure 1) with the area of 68 m^2 and in one story. This plan has living room, toilet, bathroom, one bedroom and kitchen.

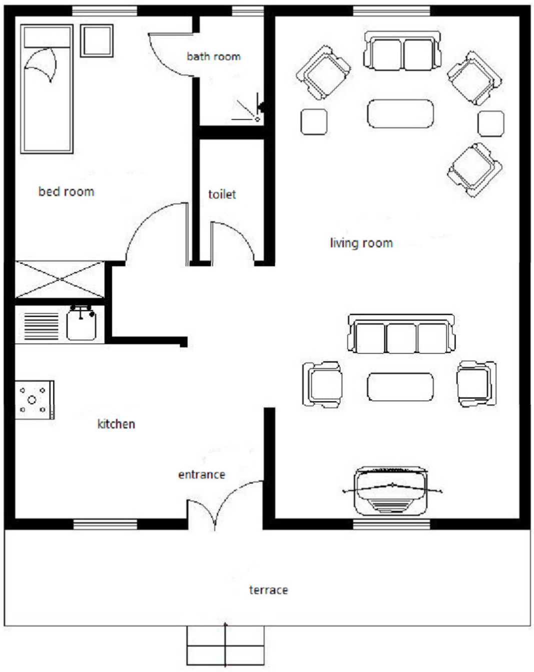

Figure1: typical plan

1.1.2 Climate data

t One of the most important variables in energy evaluation is climate data, this affects all energy outputs like total thermal, solar gain and etc. So the weather data should be imported as EPW file to simulation program which is created by Meteonorm 7 application (http://www.meteonorm.com/en/). Table 1 shows Annual characteristic of climate region of Tehran climate. Also, Tehran climate is classified as 3B climate in Grasshopper.

Table 1: Annual characteristic of climate region of Tehran climate

average dry bulb temperature	18.35 C
average dew point temperature	3.19 C
average Relative humidity	40.38%
average Wind speed	2.78 m/s
average Wind direction	233.03 degree
average Radiation	232.05 Wh/m^2
average Barometric pressure	889085.44 pa

As shown in Figure 2, most radiation comes from south direction. Therefore, for better absorption of sun radiation, the glazing ratio of the south surfaces should be more than the others.

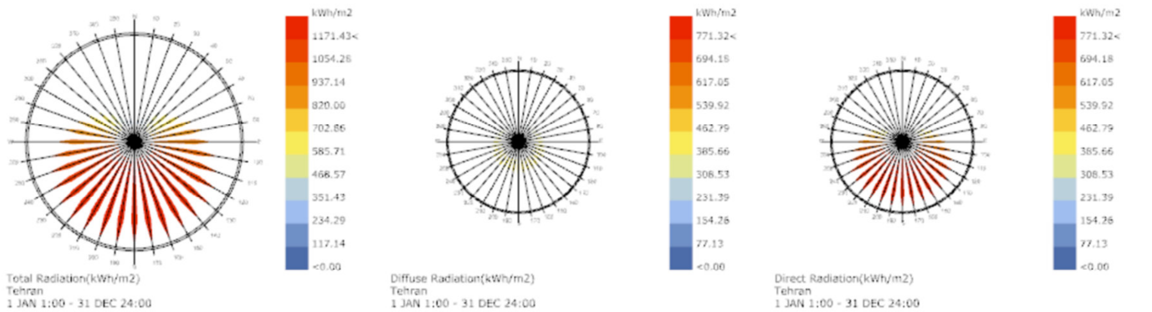

Figure 2: Tehran radiation rose

Furthermore, dominant wind for Tehran comes from North West as is shown in Figure 3, it is crucial to consider wind in design. South wind is not strong as North West wind but it is recommended to consider it in designing process.

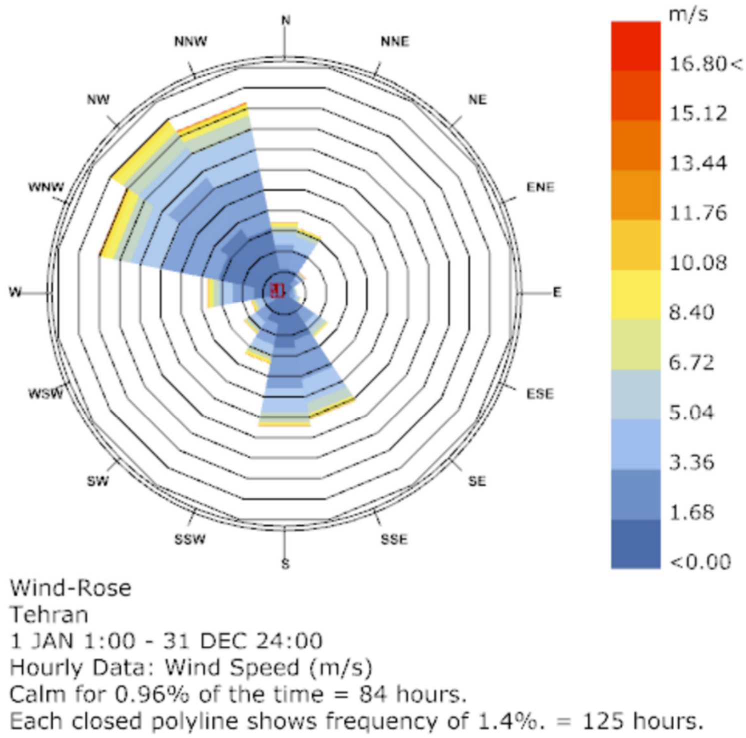

Figure 3: Tehran wind rose

1.1.3 Materials of the case study

In this case, materials are selected based on ASHRAE Standard 90.1-2010. As it mentioned before, Tehran climate is 3B and therefore all chosen materials should be suitable for 3B climate. In Table 2, all recommendation material by ASHRAE standard are shown.

Table 2: recommendation materials

Type	Recommendations by ASHRAE standard	U-value(W/m2.K)
Wall	EXTWALL MASS CLIMATEZONE 7-8	0.77
	EXTWALL MASS CLIMATEZONE ALT-RES 6-7	0.64
	EXTWALL METAL CLIMATEZONE 7-8	0.51
	EXTWALL STEELFRAME CLIMATEZONE 4-8	0.51
	EXTWALL STEELFRAME CLIMATEZONE ALT-RES 7	0.38
	EXTWALL WOODFRAME CLIMATEZONE 6-7	0.54
Roof	EXTROOF IEAD CLIMATEZONE 2-8	0.28
	EXTROOF METAL CLIMATEZONE 6-7	0.32
Floor	ATTICFLOOR CLIMATEZONE 2-7	0.15
Window	EXTWINDOW METAL CLIMATEZONE 7-8	3.6
	EXTWINDOW NONMETAL CLIMATEZONE 7-8	3.6

By considering all of these parameters, Table 3shows chosen material properties which is constant in this study.

Table 3: Material properties used in this study

Material Properties		
Floor: ASHRAE Standard 90.1-2010 ATTICFLOOR CLIMATEZONE 2-7		
Layer 1: ½ IN Gypsum Attic Floor	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.0127 0.16 784.9 830.00
Layer 2: Insulation R-35.07 IP	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.302 0.049 265 836.80
Layer 3: ½ IN Gypsum	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.0127 0.16 784.9 830.00
Wall: ASHRAE Standard 90.1-2010 EXTWALL WOODFRAME CLIMATEZONE 1-4		
Layer 1: Wood siding	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.01 0.11 544.62 1210
Layer 2: wood Frame Wall Insulation R-99.42 IP	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.0812 0.049 265 836.80
Layer 3: ½ IN Gypsum	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.0127 0.16 784.9 830.00
Roof: ASHRAE Standard 90.1-2010 EXTROOF IEAD CLIMATEZONE 2-8		
Layer 1: Roof Membrane	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.0095 0.16 1121.29 1460
Layer 2: IEAD Roof Insulation R-19.72 IP	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.17 0.049 265 836.80
Layer 3: Metal Decking	Thickness[m] Conductivity[W/m-k] Density[kg/m^3] Specific Heat	0.0015 45.006 7680 418.4
Window: ASHRAE Standard 90.1-2010 EXTWINDOW METAL CLIMATEZONE 3		
Layer 1: Fixed Window 3.69/0.25/0.16	U-factor Solar Heat Gain Coefficient	3.69 0.25

1.2 Simulation tools and details

Energy consumption is a matter of concern to many software companies. So many software`s with the ability of calculating energy use are created same as Grasshopper. It has many add-ons in energy analysis and optimization like two plug-ins Ladybug (LB) and Honeybee (HB) which are used in this research. HB evaluate energy use with the engine of EnergyPlus. LB imports climate data to Grasshopper and evaluate environmental analysis (Keshtkar banaee moghadam et al, 2017**)**. First and foremost, the building model should be defined in geometry algorithm *(http://www.grasshopper3d.com/)*. Then it should be turned to energy zones and after that energy-related subjects can be calculated by Honeybee plugin.

Clearly, in this study, the aim was finding the effect of orientation in total thermal energy and solar gain. Due to the aim, all parameters were assumed to be constant but orientation.

2. Results

The residential plan is orientated in every 30 degrees and its total thermal is measured. Figures 4 and 5 show the results visually while Table 4 shows the exact number of results. As it can be seen in Table 4, while the building is used north and south natural lighting with orientation of 180 degree, the total thermal has minimum number (2082.58kwh/y). In contrast, total thermal is maximum when the orientation is 300 degree which rooted in the direction of windows. In this situation, windows can use east and west lighting which has the minimum natural lighting based on Tehran geographical location and its radiation rose.

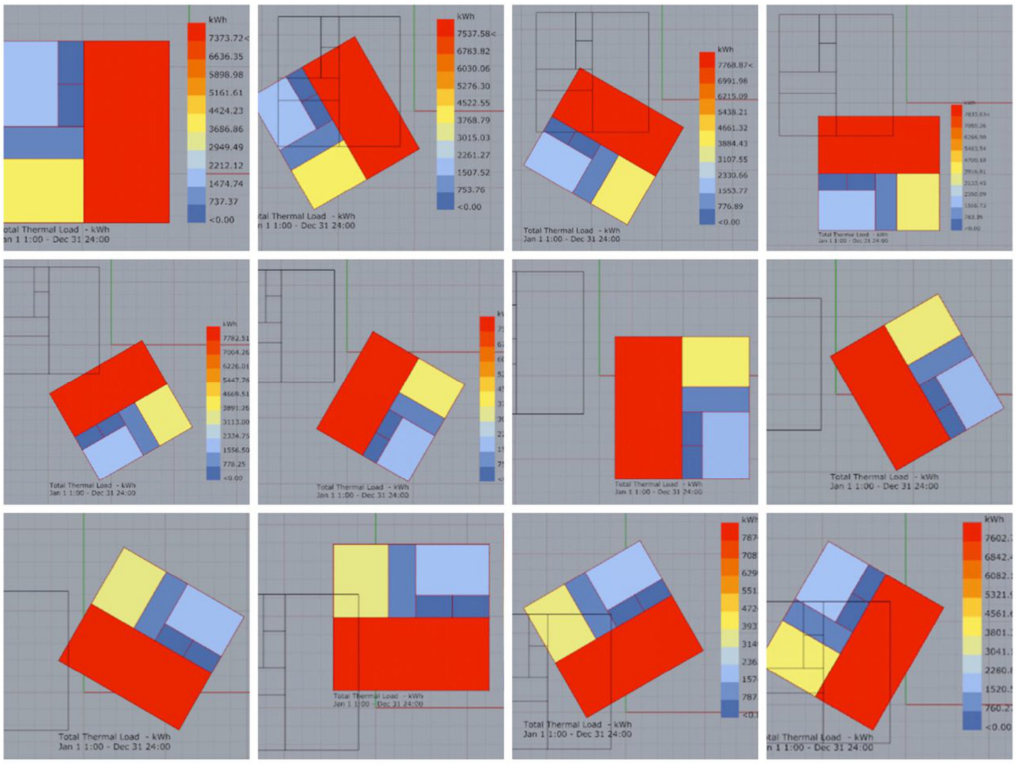

Figure 4: orientation and total thermal energy

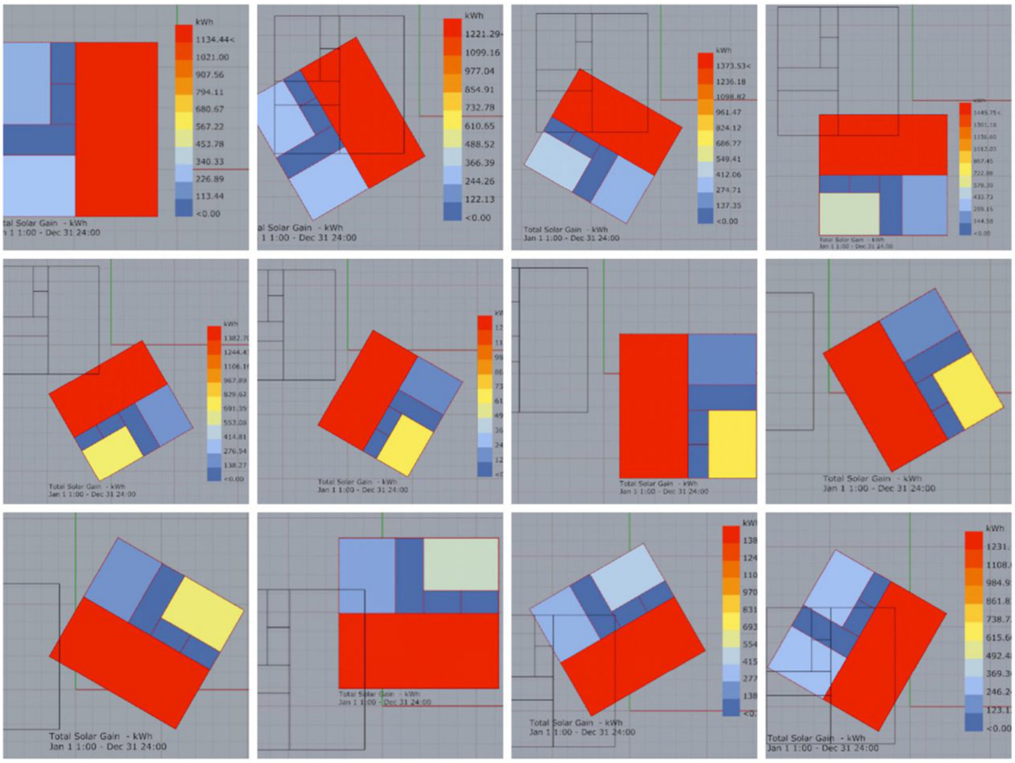

Figure 5: orientation and total solar gain

On the other hand, when the building orientated 90 degree, total solar gain is increased to maximum level. Paradoxically, solar gain is minimum at 0 degree. This clearly proves that east and west has the longest time to absorb solar radiation.

Table 4: total thermal and solar gain results based on orientation

Degree	Total thermal(kwh/y)	Total Solar gain(kwh/y)
0	2122.16	263.09
30	2167.78	287.09
60	2224.69	331.97
90	2230.58	361.07
120	2210.96	356.25
150	2140.66	324.43
180	2082.58	302.33
210	2129.18	321.89
240	2199.46	353.43
270	2227.32	360.59
300	2229.77	333.93
330	2174.12	288.97
360	2122.16	263.09

The Figure 6 illustrates comparison of total thermal and total solar gain trends. According to the graph, total thermal trend and total solar trend followed a similar pattern. At the start point, there is a steady rise and then a slight decline happened. In brief, although the peak point of these trends are entirely different from each other but their trends remain the same.

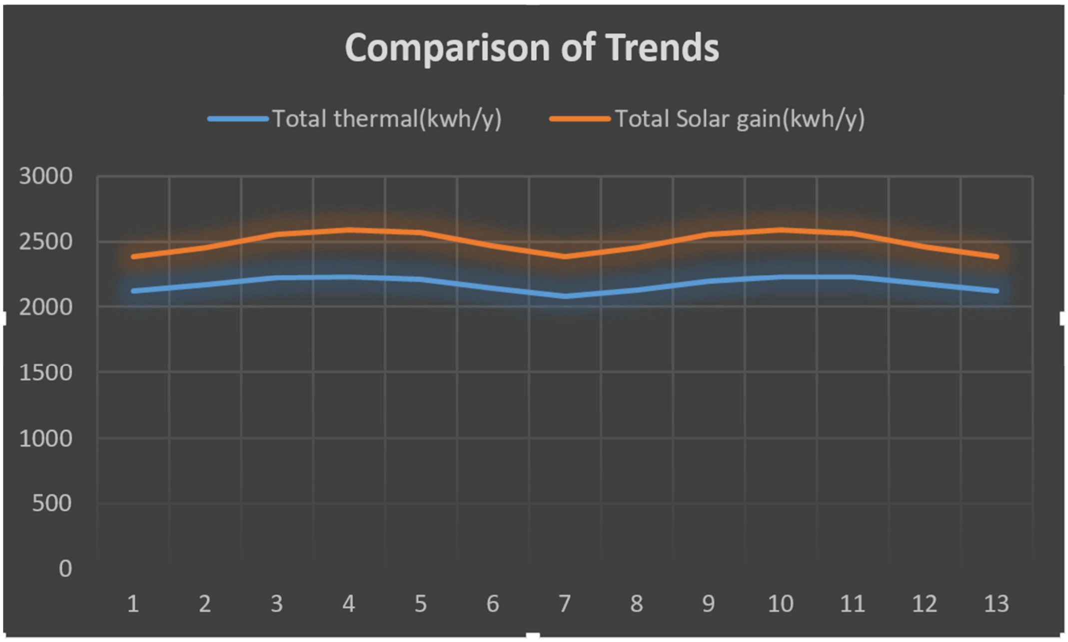

Figure 6: comparison of total thermal trend and total solar gain trend

3. Conclusion:

To put it in a nutshell, rotation had effect on total thermal and solar gain. In the light of this evidence, it is clear that south light has the maximum radiation and so it causes needed total thermal minimum. However, solar gain is in maximum level when the windows are situated in east and west direction. It's rooted in the duration of radiation which east and west can enjoy most. Although it won't be enough for designing. It is absolutely right to say that south radiation is the best radiation to use for designers in Tehran climate which caused total thermal in minimum level. In this research, all parameters are considered constantly but radiation. For future study, the effect of others parameter such as materials, number of people, infiltration rate can be investigated

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