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The Role of Buildings Forms in Energy Gain in High-rise Building through Facades (Case Study: Iran, Tehran)

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Abstract. Iran is recognized as one of the largest fossil fuels reserves resources in the world, but it is also suffer from mismanaged consumption. The consequences of this mismanagement have been considered in Iran during recent years and authorities have raised concerns about it. Identification of the optimized building form and orientation in Tehran- The capital of Iran- in order to achieve the maximum daytime heat gain by photovoltaic cells in winter is the main purpose of this paper. The results show that the best shape for high-rise building in Tehran for gaining Photovoltaic energy through south facade of building is cubic form.

Keywords: Green energy, Building Forms, Energy gain, Photovoltaic panels.

1. Introduction

Nowadays, identification of new energy resources according to science, industry and technology developments, make a significant revolution in human life. Societies' dependence on fossil fuels, the crucial role of these resources in supplying world energy demand and the current irrational consumption of them which taking a long time to form beneath the earth's surface will obviously leads to the entirely vanish of these resources in near future. Considering the environmental impacts of this carbon based energy resource, the climate change and global warming they can cause, their increasing global cost and their scarceness and not renewability. Sun, the powerful clean source of energy, is become the focus of attentions.

Iran is recognized as one of the largest fossil fuels reserves resources in the world, but it is also suffer from not managed consumption. The consequences of this mismanagement have been considered in Iran during recent years and authorities have raised concerns about it; yet, initiatives to develop energy efficient plans have been taken and in this case Targeted Subsidy Plan is one step toward this goal.

According to Iranian national building codes office declaration in 2002, constructions devote more than one-third of total energy use in this country to themselves; therefore, the major role of architecture in achieving energy efficient targets is undeniable. Investigations around alternative approaches for non renewable energy use by means of applying clean energy sources especially solar energy and taking

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advantage of new precise design trends for construction elements toward the best efficiency achievement is not only Iranian architecture deep need but also the world's architecture have to focus on that.

2. Research Questions and Inference Mechanism

2.1. Research Aims

Identification of the optimized building form and orientation in Tehran- The capital of Iran- in order to achieve the maximum daytime heat gain by photovoltaic cells and minimum energy loss at night in winter is the main purpose of this paper.

2.2. Research Questions

What are the differences between building forms in heat gain at day from building's facades?

What is the optimized building form and orientation in Tehran for photovoltaic systems best efficiency during the days?

2.3. Research Method

Research approach is simulation and modeling and applied techniques are fabrication and calculation according to case study selection. [1]

3. Building Forms and Energy Consumption

Buildings can gain heat from several resources; the building occupants, the sun, lighting and illuminations, the heating equipments and other equipments which the consumed energy by them ends up to heat. The sun is clearly the most important resource. Solar radiations are received as direct, diffuse and reflected radiations. The amount of solar heat gain is dependent on the amount of received radiant and the destination of that. Local climatic condition, the sun position, the orientation and tilt of building external elements, the surface reflectance, the thermal capacity, the area of the surface must be considered in evaluating heat gain. This stored heat is distributed through the heat transfer modes of conduction, convection and radiation.

Solar technologies are developed today to enhance the exploit of solar energy in the form of passive and active systems. The passive systems includes passive solar heating, natural ventilation, day lighting, thermal mass storage and ground cooling. Passive solar heating employs the structural elements of a building to collect, store and distribute solar energy without or with minimal use of mechanical equipment. [2] In contrast, active systems make use of mechanical techniques to capture sunlight and convert it to a beneficial form. Integration of these two methods and applying unique building designs for the best efficiency of these two systems contributed to green echo-friendly buildings and societies.

4. Case Study Selection

In Tehran, the most architects use form for high-rise buildings are slab, pyramid, and one way stair shape to three way stair shape. This case study is provided to estimate energy gain from south-facade of these types in Tehran and as a result to find the most appropriate form for this city according to the maximum energy gain in day. In order to obtain this goal, 5 buildings which all aspects including envelope, ceiling area, and used materials are the same and only different in the form of building is assumed. Based on Iranian National building codes every high-rise building must use maximum 40% of its facades as opening and windows. [3] The following is a description of the parameters used for calculations.

Roof types: Slab roof (Roof 0)

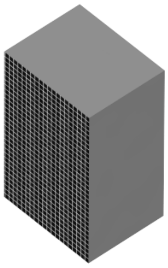
Surface angle: 90

Ceiling area: 200 m^2 (length is 50m and width is 20m)

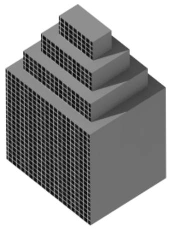
Air temperature inside the building: 25 c (298.15 k)

Location: Tehran, Iran (latitude: 35.7 north and longitude: 51.4 east)

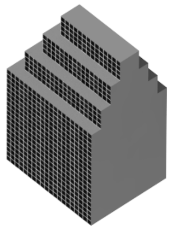
Windows and Openings: 40% of facades area



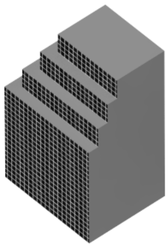
Cubic shape



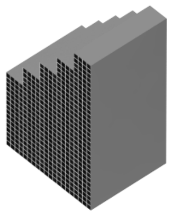
Pyramid shape



Three way stair shape



Two way stair shape



One way stair shape

Building Shape	cubic	On way stair	Two way stair	three way stair	pyramid
Total Facade Area	4000 m2	3000 m2	3700 m2	3700 m2	3400 m2
Usable Facades Area	2400 m2	1800 m2	2220 m2	2220 m2	2040 m2

5. Photovoltaic Energy at Day

In this part the amount of heat gain for the five types of buildings is investigated to find out the most appropriate high-rise building shape for installing photovoltaic arrays. The output from the arrays depend on the daily variation due to the rotation of the earth and the seasonal one, Location (the solar radiation available at the site), tilt and azimuth (orientation with respect to due south),shadowing and temperature. [4]

For unshaded installations the approximate monthly energy production of the system is calculated by following equation: [4]

$$E = S \times K \times L$$

S = uncorrected daily output in KWh/day

K = combination the loss due to temperature and a number of others such as dust, (assumes 0.9).

L = losses in the other components (power conditioning unit, wiring, etc), (assumes 0.8). The **S** parameter is calculated by following formula:

$$S = \text{Array's Area} \times \text{Module efficiency} \times \text{Monthly average insulation of the surface}$$

The efficiency of Photovoltaic arrays is dependent to their type. Among ***monocrystalline silicon***, ***polycrystalline silicon*** and ***thin film silicon modules*** the monocrystalline one has the best efficiency about 12-15% under standard test conditions (STC).

To estimate the monthly average insulation on the roofs, as this parameter has different amounts for different tilt of a surface, 3 different calculations must be done. For horizontal surfaces this parameter could be derived from NASA information and for tilted surface due to the following formula it can be calculated according to the tilt angle.(Liu and Jordan.1963). [5]

$$H_T = H\left(1-\frac{H_d}{H}\right) R_b + H_d\left(\frac{1+\cos\beta}{2}\right) + H\rho\left(\frac{1-\cos\beta}{2}\right)$$

$\boldsymbol{H_T}$: Monthly Averaged Insulation on a tilted Surface

$\boldsymbol{H}$: Monthly Averaged Insulation Incident On a horizontal surface (KWh/m2/day)

$\boldsymbol{H_d}$: Monthly Averaged Diffuse Radiation Incident on a horizontal surface (KWh/m2/day)

$\boldsymbol{R_b}$: The proportion of the beam radiation on a tilted surface to beam radiation on a horizontal surface. It's calculated through monthly averaged declination of sun and latitude of the location.

$\boldsymbol{\beta}$: Tilt of the surface in degree 90

$\boldsymbol{\rho}$: face's reflectivity, assume an average value of 0.2

$\boldsymbol{\Phi}$: latitude of Tehran which is 35.7

According to the NASA data, the following parameters are used in calculations for Tehran (latitude 35.7 and longitude 51.4) in December. [6]

$H = 2.38$, $H_d = 0.82$, $= - 22.8$

It is assumed that the surface of roof which is covered with the photovoltaic arrays is sloped toward the equator and a $50m^2$ monocrystalline silicon array (efficiency 15%) is applied. For achieving to R_b, firstly must calculate w_s and w'_s with the help of these equations:

$$w'_s = \min \begin{cases} \cos^{-1}(-\tan\delta \cdot \tan\Phi) \\ \cos^{-1}(-\tan\delta \cdot \tan(\Phi-\beta)) \end{cases} \qquad w_s = \cos^{-1}(-\tan\delta \cdot \tan\Phi)$$

$$R_b = \frac{\cos(\Phi-\beta)\cos\delta\sin w'_s + \left(\frac{\pi}{180}\right) w'_s \sin(\Phi-\beta)\sin\delta}{\cos\Phi\cos\delta\sin w_s + \left(\frac{\pi}{180}\right) w_s \sin\Phi\sin\delta}$$

Table 1: Total amount of energy gain of each building shape m^2, designed by authors.

Building Form	H_T (KW/m2/day)	S (KW/day)	K	L	E (KW/day)
Cubic shape	2.38	1036.44	0.9	0.8	746.24
Pyramid shape	2.38	880.97	0.9	0.8	634.30
One way stair shape	2.38	777.33	0.9	0.8	559.68
Two way stair shape	2.38	958.71	0.9	0.8	690.27
Three way stair shape	2.38	958.71	0.9	0.8	690.27

6. Conclusion

As a result for finding out which shape is the most efficient, in table 3 compares the results of heat loss and energy gain. The role of building forms in energy gain in high-rise building through facades in case of Tehran shows in the chart.

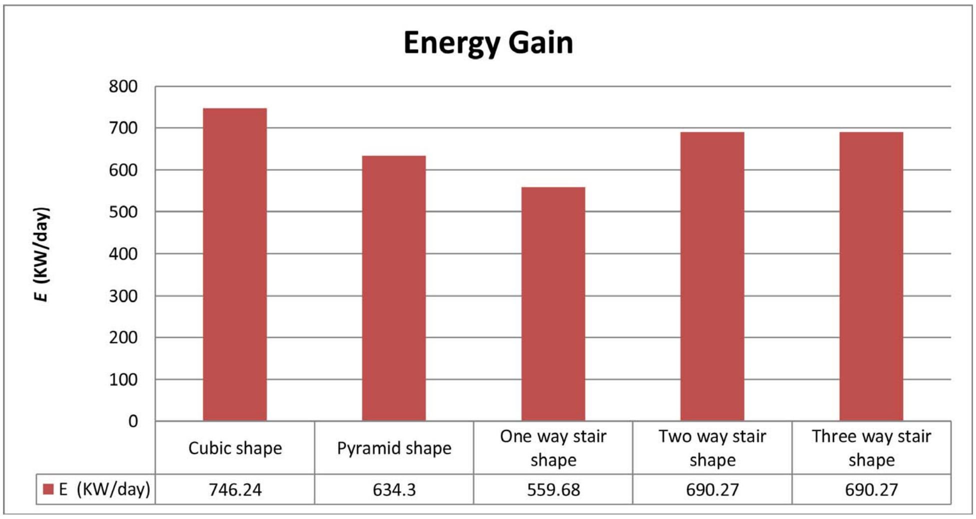


Table 3: Comparison between heat loss and energy gain, designed by authors.

According to the data from table 3, cubic shape high-rise buildings are the best case for Tehran in purpose of gaining more energy through south-facades

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