CONTEXT COMFORT FEATURE IMPROVEMENT REGARDING URBAN BLOCKS DESIGNING BASED ON MAXIMAL UTILIZATION OF PASSIVE SOLAR ENERGY; CASE STUDY: LATMAN KAN RESIDENTIAL SITE

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ABSTRACT:
Solar energy utilization to achieve a thermal comfort and energy saving is of a remarkable importance. For this purpose, it is necessary to found buildings in a way for them to be exposed with the winter sunlight, maximally benefit the sunlight. Due to the increasing number of high-rise urban constructions, it seems necessary to set up mandatory regulations for both architects and urban planners in order to gain adequate solar accessibility for building blocks. Researches done suggest that a generic energy efficient building form derives from cutting solar profiles in a conventional block. Architects and urban planners should identify the effective factors in this field and use them in their designs. The purpose of this study is to identify the effective factors on maximizing the potential of passive solar energy utilization. Due to increasing urban density, the issue of distances between blocks is of great importance and should be determined according to building heights for adjacent apartment blocks and solar profiles. This study, after introducing some strategies, computes these ratios in Tehran, Tabriz and Yazd in the three cold months of the year, November, January, March, and at the three hours of the day. It also studies a residential town's amount of ghosting and solar energy loss due to ignoring the proper distance necessary between blocks.

KEYWORDS:
Building density, Passive solar energy, Solar geometry, Urban blocks

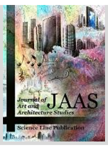
1. INTRODUCTION

Nowadays, due to population increase, we see an increasing trend of high-rise building blocks. Population increase leads to a rise in energy consumption and the limited access and the pollution created by fossil fuels consumption have made it inevitable for human beings to tend to renewable sources of energy. Solar energy is one of the renewable forms of energy the use of which, especially for heating in cold months of the year, is of remarkable consideration. Hence, it is necessary to base urban blocks designing, in both urban planning and architectural designing, on the maximal utilization of solar energy. The ratio between adjacent blocks' distance and height of them is one of the effective factors in building utilization rate of solar energy which is determined by solar altitude and solar azimuth and depends on the desired area latitude.

In this paper there are studies to present some rules for proper urban blocks design with maximum passive solar energy access, and then by comparing these rules with the current Iran municipalities' regulations, recommendations for improving the conditions for taking maximum advantage of passive solar energy are presented.

2. MATERIALS AND METHODS

The distance between adjacent urban blocks has large impact on solar energy absorption by them. Proper distance between adjacent buildings depends on their height, latitude, solar azimuth and solar altitude, so it is different in each city, each month and each hour. Because using passive solar energy for buildings heating is raised more in cold seasons, in this paper by using statistical data the coldest months of the year in Tehran, Tabriz and Yazd were determined (Figure 1). The coldest months of the year in these three cities are since November to March. Then, according to solar geometry, calculations to determine the proper distance between urban blocks based on their height for those three cities were done for three days: November 15, January 15 and March 15 and at three hours: 8 AM,



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12 PM, 4 PM and the results were presented in (Table 1).

In this study also by simulation solar radiation according to solar geometry, a residential town in Tehran was studied and ghosting mode of its southern blocks on the northern ones, the amount of received and missed solar energy on the southern facades of the northern blocks as well as their percentages of shaded areas and number of shaded floors in November 15, January 15 and March 15 and at 8 AM, 12 PM, 4 PM were calculated (Tables 2 to 4 and Charts 1, 2).

3. The concepts of solar rights and solar envelope

The analyses of solar insulation patterns of high-density apartment blocks require introducing two basic concepts. The first is “Solar Rights”, and the other is “Solar Envelope” [1].

3.1 Solar rights

“Solar rights” is defined as the right to have solar radiation accessibility without any obstacles from any adjacent objects. “Solar Rights” implies that new structures must never shadow the roof of any existing building. Determining suitable vertical limits of sites under consideration is a good solution for this problem [1].

3.2 Solar envelope

“Solar Envelope” has been developed by Knowles to integrate urban and building design with solar accessibility. It may be defined as the maximum built volume that allows solar radiation to hit adjacent sites. Solar envelope, therefore, is related to site size, orientation, latitude, and the amount of allowable shading on adjacent streets and buildings [2].

“Solar Collection Envelope” is defined as the lowest possible locus of windows and passive solar collectors on the elevations of a building, in which they are maintained exposed to sun during a specific period [1].

4. Effective factors in the maximum absorption of solar energy by urban blocks

4.1 Proper orientation of buildings

To prepare the best thermal conditions indoors (warm air in winter and cool in the summer) the main facade of the building should face to south. Although the southeast and southwest facades of the building receive the sun more uniformly, they are warmer in the summer and cooler in the winter than the south facade.

4.2 Designing appropriate form for urban blocks

Generally urban blocks forms can be classified into two categories: 1- The linear urban form, 2- The block urban form. Each one of them has advantages and disadvantages. For example the linear urban form – in the case of appropriate setbacks and proper orientation – in terms of solar accessibility is well efficient, but visually, it is a monotonous form in which it is difficult to well define open spaces and to differentiate between different categories of open spaces. To the contrary, the block urban form produces two different types of well defined open spaces. Backyards offer a quiet and safe place for semi-private outdoor living, which allows neighbors to meet and helps to build community. But from the solar point of view the residential block could be seen as an inefficient form for the following reasons:

- Some of its sides are either unfavorably oriented to the sun and/or suffer from mutual overshadowing.
- The solar energy falling on the facade is poorly distributed; leaving many areas in the building with extremely low solar radiation while other areas receiving most of the solar energy.

By combining these two forms, a third one called "The Residential Solar Block" will be achieved. The Residential Solar Block (RSB) is a building form developed with the aim of achieving the functional, spatial, social and visual advantages of the conventional residential block with the energy efficiency advantages of the linear urban form. It could be derived from a conventional block with sides facing NE, SE, SW and NW using the method of cutting solar profiles in cold seasons for the selected latitude [3].

4.3 Using collector facade

Collector facade is an article in which solar solution for taking advantage of the solar energy to heat a high-rise building in Tehran has been recommended as converting existing facade into solar collector. The building that collector facade has been proposed for, is a 14-storeys office building which northern, western and southern facades are made of heat-absorbing double glazing glass. The building facades glass walls have 4 and 6 mm in thickness, respectively for internal and external side placed in an aluminum frame with 1 cm distance between the two glasses. To convert the existing facade to a collector one, a glass wall on the southern side and another one on the northern side of the building were offered to be added. The distance between the new facade and the old one is 30 cm in the southern side and 10 cm in the northern one and the air will flow through the channels embedded in the false ceiling and floor. In order to prevent gathered heat loss and remove local heat, the height of the facade is limited in every two stores of the building and in 10 m in width. As a result, smoke will not transfer to other classes in case there is a fire and during the day, the noise will not transfer from the lower floors to uppers. It should be noted that the exterior side of the former facade glass must have a reflective layer in the range of 90%, in order to receive heat from solar radiation energy after adding a new facade.

In the collector facade, the existing air in the 30 cm distance between the two southern facades is heated up in the sunlight and moves upwards. Then, it is conducted to the northern part through channels embedded in the ceiling. The warmed air after passing through the false ceiling enters into the 10 cm distance between the two glasses of the northern facade and there, it is cooled due to exchange with surfaces of glass and moves downside. Then, the cooled air is returned to the southern facade again to get warmed through channels existing in the false floor.

The results of the study indicate that in the median span, the amount of absorbed useful energy is always greater than the required energy due to the small external surface of northern and southern apartments. Therefore, these methods can be used simply in the cold times of the year to provide northern and southern apartment with all the heating in median span in sunny hours. Approximately 63% in eastern apartments and in western ones due to large glass surfaces and lots of heat wasting to the outside, about 31% of the required energy in the winter is provided by the collector facade. Meanwhile in those all three spans the absorbed energy is much more than the thermal needs, during the autumn days [4].

4.4 Consideration appropriate distance between buildings

The distances between urban blocks affects on the relationship between apartments and the sun. Having a solar envelope design helps effectively to reduce the heat load in the cold season. Distances and setbacks between apartment blocks imply the importance of urban density and urban compactness in respecting solar rights and solar accessibility [1].

5. URBAN DENSTY

The idea of density increase is based on that the high density -its definition according to different societies is different but recognizable- can solve many of the problems associated with the limitations especially the land and costs, and in this regard it can prevent from land wasting as the natural and vital main cause of development of cities. The other justification is economic, the low density -its definition according to different societies is different but recognizable- leads to increasing the cost of urban infrastructure and this can increase the services [5].

Against these advantages with density increase, the flexibility in deployment and orientation of residential units for proper lighting and natural ventilation will decrease and buildings will be more likely in the shade. This particularly may happen more in constructions with unusual dimensions, orientation and topography land. The more density, the less private open spaces, and climatic design of residential units become more important [6].

It is essential to consider various factors such as occupancy rate and coefficient of concentration of population in urban comprehensive plans.

Different densities in the city are classified as follows:

- Dispersed urban centers (low density)
  120up to 150 people Ha
- Semi-dense urban areas (medium density)
  150 up to 300 people Ha
- Dense areas (high density)
  more than 300 people Ha
- Rural areas
  1 up to 20 people Ha

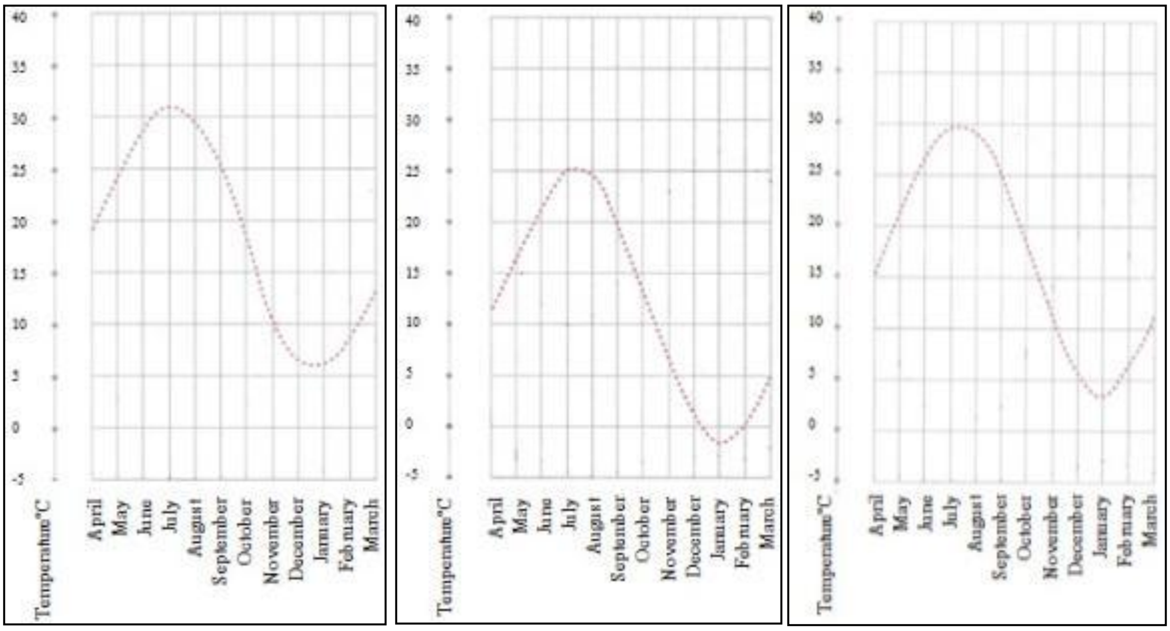
Dispersed areas of the city are typically areas that have dispersed buildings with limited and short (max 2-storeys) height which are open and almost semi-rural. In semi-dense areas, it is possible to implement various types of constructions and it is necessary to have proper relation between the height of buildings and the distances among them. In dense areas, maximum usage of surfaces of urban lands and buildings height is applied according to the position of the city comprehensive plan [7].

6. CURENT LAWS

According to regulations adopted by the Supreme Council for Planning, the minimum area for open space in a residential complex should not be less than 40% of the land area. In addition, the edges of sidewalks adjacent buildings should setback as much as a quarter of the maximum building height and the resulted area in calculating open space should be considered as common space. The distance between buildings with the same orientation should not be less than half the total height of the two buildings [8].

7. COMPUTATIONS TABLE

Proper distance between buildings depends on latitude, solar azimuth and solar altitude. In the following, after introducing solar geometry, in the Table 1 the proper distances between urban blocks is presented as a ratio of their height for Tehran, Tabriz, Yazd, in the three cold months of the year and at the three times of the day – 8:00 AM, 12:00 PM and 4:00 PM -. Because according to Figure 1 the coldest months of the year in these three cities are since November to March, the calculations have been done for these three months: November, January and March.



Tehran, 25-years statistics average (1951-1975)

Tabriz, 25-years statistics average (1951-1975)

Yazd, 24-years statistics average (1952-1975)

Figure 1. Climatic specifications (temperature) for Tehran, Tabriz, [9].

8. SOLAR GEOMETRY

Mathematical sciences relevant to the position of the Sun in the sky and the angles between Sun beam and the Earth and its different levels is called as solar geometry. The angles are defined as follows:

θ: Latitude
δ: Declination Angel
ω: Hour Angel
γ_s: Solar Azimuth
α: Solar Altitude
γ_p: Considered surface Azimuth (In here = zero)
β_v: Incident Angel for vertical plane

$$\delta = 23.45 \sin\left[360 \left(\frac{n}{365}\right)\right] \qquad \omega = \pm 0.25 \times t$$

$$\sin\alpha = \sin\delta.\sin\theta + \cos\delta.\cos\theta.\cos\omega$$

$$\sin\gamma s = \frac{\cos\delta.\sin\omega}{\cos\alpha} \quad [10]$$

According to Figure 2, the relationship between buildings height and distance between them is as follows:

$$\tan\alpha = \frac{H}{X} \qquad X = \frac{S}{\cos\gamma_s}$$

$$\cot PA = \frac{S}{H} = \frac{\cos\gamma_s}{\tan\alpha}$$

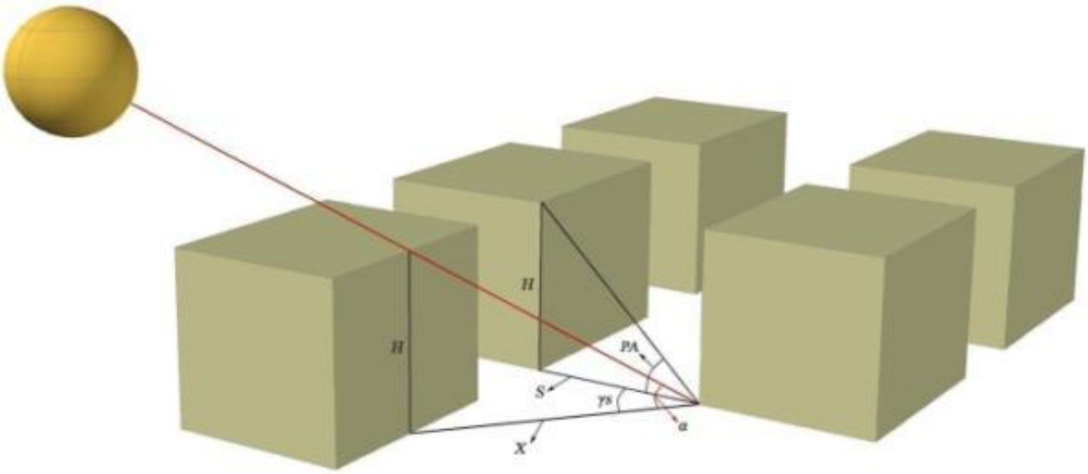


Figure 2. The relationship between buildings height and distance between them based on solar Profile, [Author].

In winter the distance between the buildings is much more sensitive because solar altitude is less than summer and using passive solar energy for buildings heating is raised more in cold seasons. By using mentioned formulas, solar profiles and buildings distances based on their height were calculated for Tehran, Tabriz, Yazd and the results were presented in (Table 1).

8.1 Some points about Table (1)

- Because the above calculations have been done for the southern facade, the azimuth for the surface is zero.
- Solar altitude is the same at 8 AM and 4 PM of each day.
- Solar azimuth at 8 am is equal to the negative value of solar azimuth at 4 pm of the same day.

Table 1. Solar profiles and buildings distances based on their height for Tehran, Tabriz and Yazd, [Author].

Name of city	Time	Hour	Latitude [9]	Declination Angel	Hour Angel	Considered surface Azimuth	Solar Azimuth	Solar Altitude	The minimum northern and southern distance between buildings based on adjacent buildings height[1]
Tehran	November 15	8 AM	35.41	-17.34	60	0	57.82	12.46	2.41 H
		12 PM			0		0	37.21	1.32 H
		4 PM			-60		-57.82	12.46	2.41 H
	January 15	8 AM		-22.42	60		54.14	8.96	3.71 H
		12 PM			0		0	32.17	1.59 H
		4 PM			-60		-54.14	8.96	3.71 H
	March 15	8 AM		-5.59	60		66.89	20.43	1.05 H
		12 PM			0		0	49	0.87 H
		4 PM			-60		-66.89	20.43	1.05 H
Tabriz	November 15	8 AM	38.08	-17.38	60	0	57.36	11.03	2.77 H
		12 PM			0		0	34.54	1.45 H
		4 PM			-60		-57.36	11.03	2.77H
	January 15	8 AM		-22.42	60		53.83	7.39	4.55 H
		12 PM			0		0	29.50	1.77 H
		4 PM			-60		-53.83	7.39	4.55 H
	March 15	8 AM		-5.59	60		66.01	19.37	1.16 H
		12 PM			0		0	46.33	0.95 H
		4 PM			-60		-66.01	19.37	1.16 H
Yazd	November 15	8 AM	31.54	-17.38	60	0	58.61	14.50	2.01 H
		12 PM			0		0	41.08	1.15 H
		4 PM			-60		-58.61	14.50	2.01 H
	January 15	8 AM		-22.42	60		54.70	11.21	2.91 H
		12 PM			0		0	36.04	1.37 H
		4 PM			-60		-54.70	11.21	2.91 H
	March 15	8 AM		-5.59	60		68.28	21.91	0.92 H
		12 PM			0		0	52.87	0.76 H
		4 PM			-60		-68.28	21.91	0.92 H

[1] In this paper the ground is assumed flat. In the case of slope ground, these ratios will change and it should be considered in calculations.

9. CASE STUDY

The case study of this paper is Latman Kan residential site located in District 22 of Tehran. This site is located at the intersection of Kaj and Amir Kabir Blvd and at the adjacent with Shahab town (Figures 3, 4).

In this study (according to Figure 4) Ghosting mode of blocks No. 4,5,6 on the blocks No.1,2,3, the amount of received and missed solar energy on the southern facades for sum of the three blocks No.1,2,3 and also the percentage of shaded area and the number of classes of blocks No.1,2,3 which located in the shadow, in the three cooler month of the year –November, January, March- and at the three hours of a day have been studied and the results are presented in the Tables 2 to 4 and at the Figures 1 and 2.

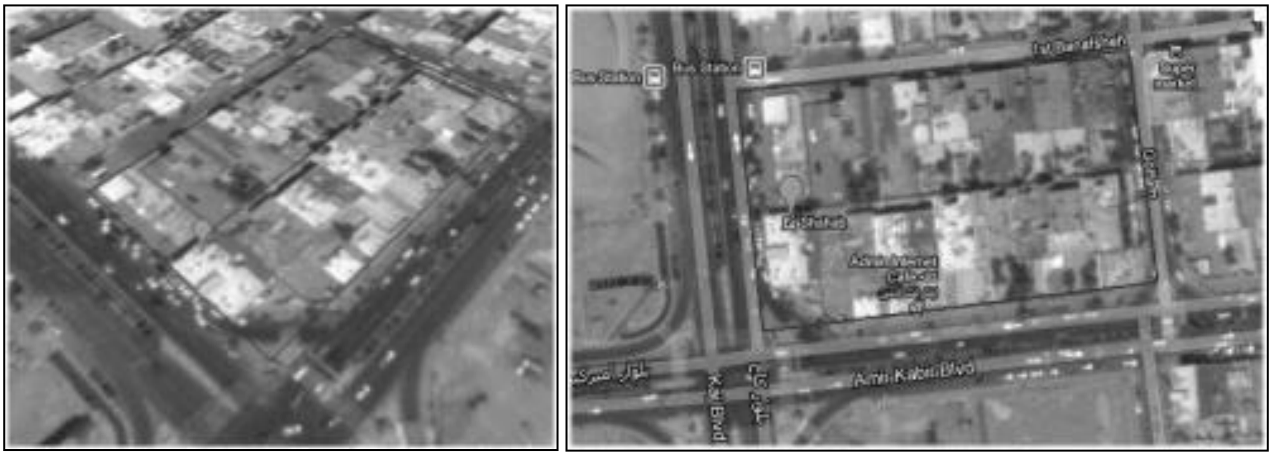


Figure 3. Latman Kan residential site's map and the status of under study's blocks [11].

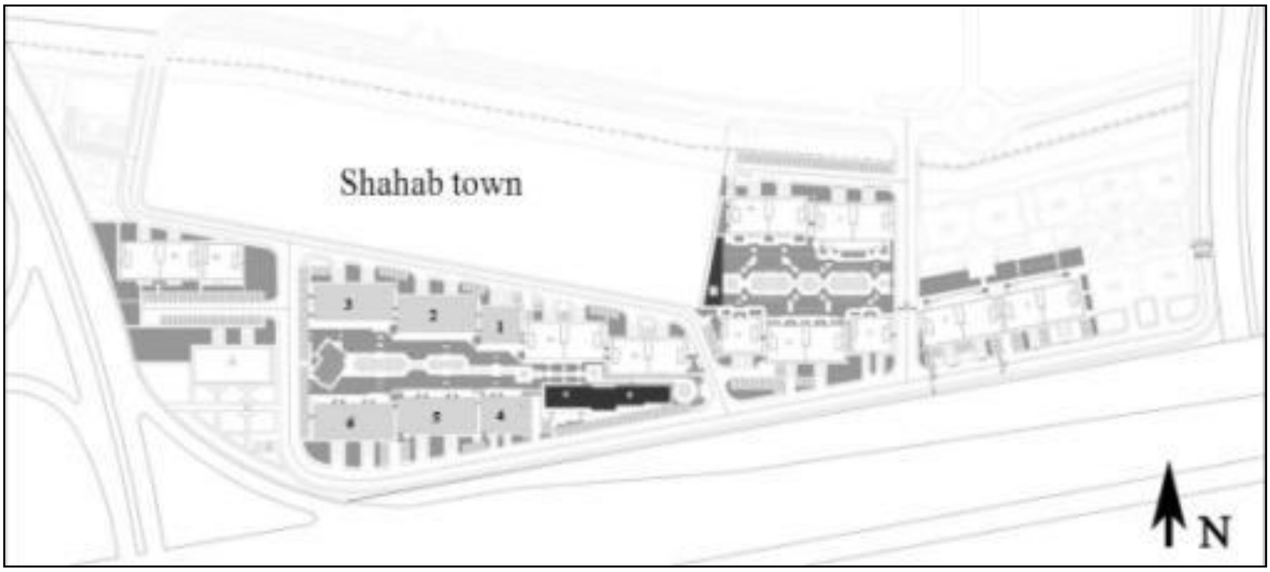


Figure 4. Latman Kan residential site's map and the status of under study's blocks, [12].

Table 2. Amount of received and missed solar energy on the southern facade for summation of three blocks NO. 1, 2,3, [Author].

Time	Date	Solar radiation on vertical surfaces in Tehran[2] (BTU/h/ft²)	Area of southern facade (ft²)	Southern facade maximum absorbable solar energy (BTU/h)	Received solar energy by southern facade (BTU/h)	Missed solar energy (BTU/h)
8 AM	November 15	61		2535813.31	208091.72	454902.59
	January 15				1799454.35	736358.96
	March 15				253581.31	0
12 PM	November 15	204	41570.71	8480424.84	7733397.01	747027.83
	January 15				7017831.89	1462592.95
	March 15				8480424.84	0
4 PM	November 15	62		2577384.02	2093904.73	483479.29
	January 15				1848293.39	729090.68
	March 15				2577384.02	0
Sum				40780866.51	3616741.21	4613452.3

Table 3. Ghosting mode of blocks NO. 4, 5,6 on the blocks NO. 1, 2, 3 [Author].

Time \ Date	November 15			January 15			March 15		
	Block NO.1	Block NO.2	Block NO.3	Block NO.1	Block NO.2	Block NO.3	Block NO.1	Block NO.2	Block NO.3
8 AM									
12 PM									
4 PM									

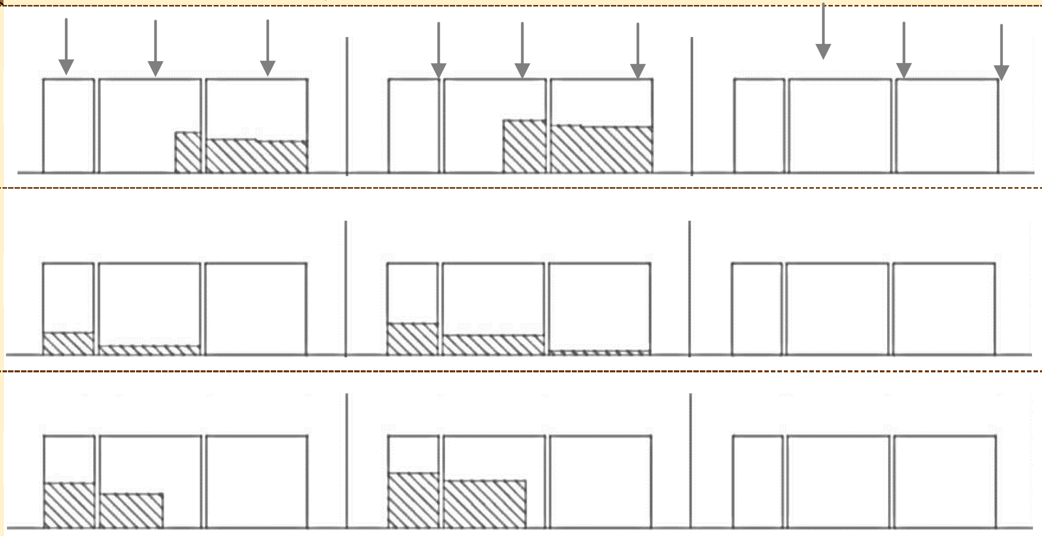


Table 4. Percentages of shaded areas and number of shaded floors of blocks NO. 1, 2, 3, [Author].

[2]The numbers according to the table below have been obtained from the average of available numbers on the charts of latitude 33 and 37 degrees. [9]

Hour \ Latitude	33°north	37° north	35.41° north (Tehran)
8 AM	80	42	61
12 PM	204	204	204
4 PM	76	48	62

Date	Time	Percentages of shaded areas of southern facade			Shaded floors [3]		
		Block NO.1	Block NO.2	Block NO.3	Block NO.1	Block NO.2	Block NO.3
November 15	8 AM	0	10.64	34.13	0	western $5\frac{1}{3}$	$4\frac{1}{3}$
	12 PM	24.46	9.86	0	$3\frac{1}{8}$	$1\frac{1}{3}$	0
	4 PM	48.43	22.81	0	6	central + eastern $4\frac{3}{5}$	0
January 15	8 AM	0	23.23	49.24	0	western + a part of central $6\frac{4}{5}$	6
	12 PM	34.14	21.67	4.45	$4\frac{1}{4}$	$2\frac{4}{5}$	$\frac{3}{5}$
	4 PM	59.41	41.15	0	$7\frac{1}{4}$	central + eastern + half of western $6\frac{1}{4}$	0
March 15	8 AM	0	0	0	0	0	0
	12 PM	0	0	0	0	0	0
	4 PM	0	0	0	0	0	0

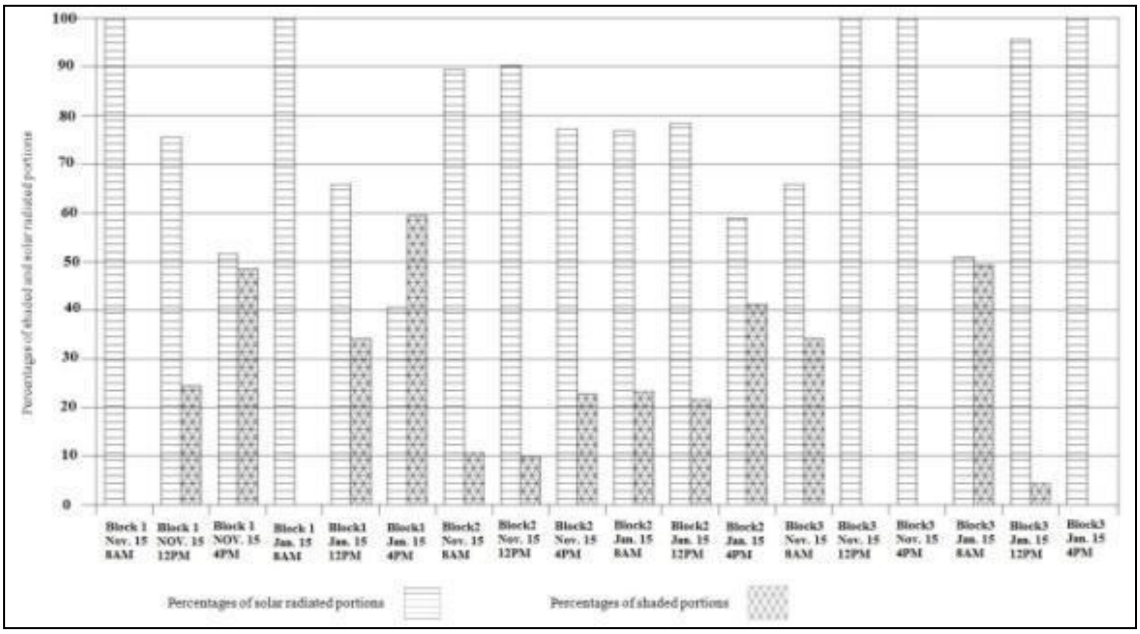


Figure 5. Percentages of shaded and solar radiated portions of southern facade for blocks No.1,2,3 in November 15th, January 15th and at 8 AM, 12 PM, 4 PM [Author].

[3] Because according to Table No.3, sometimes the whole area of width of block No.2 isn't covered by shadow, the southern facade of this block hypothetically has divided into 3 vertical divisions and in the Table No. 4 has mentioned as Eastern, Central and Western. This indicates the importance of the windows locations on the building facade. Therefore, the designer should determine the location of the windows so that they can take the most benefit from the sunlight during the day.

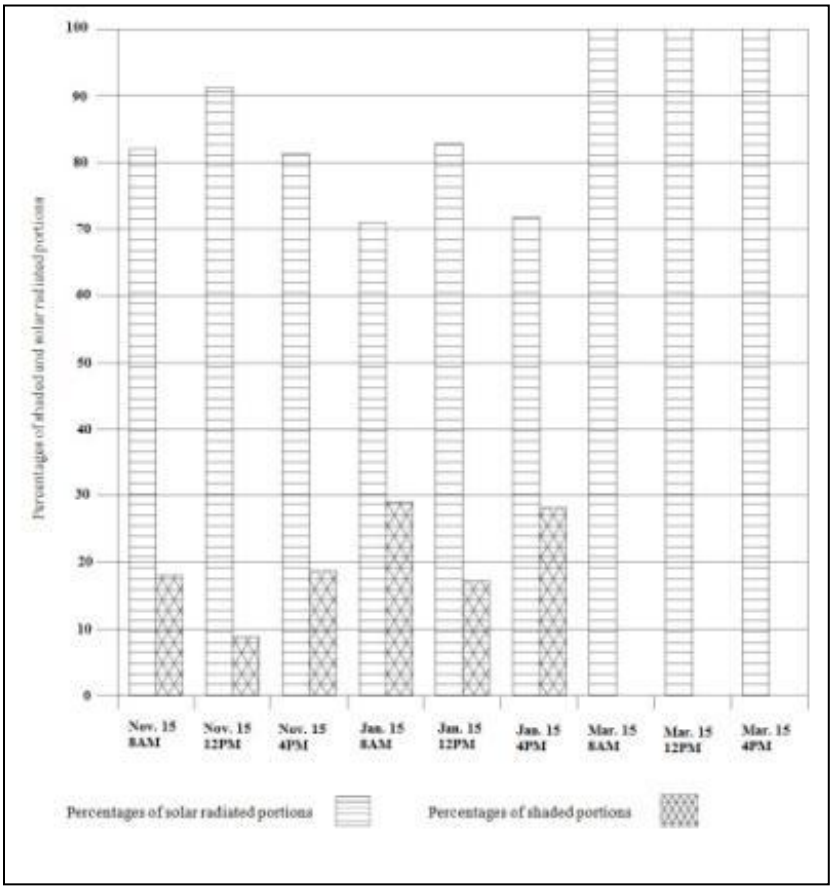


Figure 6. Percentages of shaded and solar radiated portions of southern facade for summation of three blocks No.1,2,3 [Author].

According to the tables and figures presented, the following conclusions are reached:

- In March, there is no ghosting on blocks No. 1, 2,3 and in this month, the blocks can take maximum advantage of solar energy radiated.
- To the contrary, we can see maximum ghosting in January.
- In each three months, because solar altitude is closer to perpendicular, the lowest ghosting occurs at 12 PM

10. RESUITS AND DISCUSSION

This investigation has been done to present strategies to increase urban blocks' utilization of solar renewable energy. There are several factors influencing on urban blocks utilization of solar energy. The following items can be mentioned:

- Blocks orientation to the south.
- Choosing the appropriate geometry for blocks so that it can respond to functional requirements and be useful in terms of solar energy accessing, as well.
- Using specific measures such as collector facade.
- Proper spacing between buildings relative to their height. The distance between blocks depends on solar azimuth and solar altitude that are variable in every city, every day and every hour.

Municipalities and legislative authorities should make clear and mandatory regulations and make architects and urban designers follow them to even lower levels of buildings take advantage of solar energy during cold seasons of a year. For this purpose the worst condition in terms of ghosting should be considered. According to the tables and charts presented in this study, the worst month is January and it should be used as a basis. In this study, the ratios between the distances and heights of buildings for Tehran, Tabriz and Yazd have been calculated. The calculations should be done for all latitudes and must be presented as mandatory rules. It should be noted that in the case of slope ground, the ratios will change (like the case study in this paper) and it should be considered in calculations.

At the end, as this study was conducted only for south oriented facades, it is recommended that future studies be conducted for other facade orientations.

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