Armanshahr Architecture & Urban Development, 9(16), 85-94, Spring Summer 2016
ISSN: 2008-5079

Best Orientation Determination of Buildings in Zanjan City Based on Solar Radiation

Mahdi Zamani[1*], Hassan Akbari[2] and Faramarz Hadavi[3]

[1] Ph.D. in Geomorphology, Islamic Azad University of Tehran, Science and Research Branch, Tehran, Iran.

[2] Assistant Professor of Architecture, Faculty of Technical and Engineering, University of Mohaghegh Ardabili, Architecture Department, Ardabil, Iran.

[3] Ph.D. Student of Geography and Urban Planning, Department of Geography, Payame Noor University, Tehran, Iran.

Received 12 July 2014; Revised 27 October 2015; Accepted 28 October 2015

ABSTRACT: In recent years, high consumption of energy has become one of the major problems of world, especially in big cities. One of the solutions given for this situation is using solar energy as much as possible. If buildings are constructed in accordance with solar radiation and regional climate, they can absorb the lowest energy in hot and the most energy in cold periods; there will then be noticeable saving in energy consumption. Since Zanjan has special location, the buildings' orientation should be in a way that the most possible energy could be absorbed by the building through the cold periods, and the lowest amount of energy would be able to hit the building in hot periods. In this research, to reach the most efficient use of solar energy in Zanjan, as the case study of research, first the climate information of 40 years timing was collected from Zanjan Synoptic Center, and the orientation and height of sun was extracted afterwards by using Q-BASIC software. The amount of solar radiation on vertical surfaces of walls in various angles was calculated using law of cosines. And finally the best orientation for buildings in this city has been determined. The results of this research showed that vertical surfaces with the orientations of +150 and -150 south-west absorb the most amount of energy, and the surfaces with orientations of +15 and -15 north-east and west absorb the lowest energy in cold and hot months of the year. The highest difference of radiated energy in vertical surfaces is at +135 south - east and – 135 south-west through hot and cold periods. According to the research results, the best settlement orientations for buildings are 135 degree and 225 degree of Azimuth angle.

Keywords: Solar Energy, Zanjan, Building Orientation.

INTRODUCTION

High consumption of energy is one of the current century's problems in human societies, and meanwhile, the most consumption relates to fossil fuels. This issue has caused many problems including: 1. Supplying energy from non-renewable fossil fuels resources, 2. an increase in greenhouse gases as a result of using such fuels. Various international organizations have been founded and many studies have been carried out to deal with this issue. For example in 1990, Intergovernmental Panel Climate on Change (IPCC) was established. According to the published reports, greenhouse gases growth will enhance global warming between 1.5 to 4.5 degree and will rise sea level about 20 to 140 centimeters by the year 2030 (Azizi, 2004). This problem is more noticeable in cities because of their high density of population. Vehicles and buildings in cities lead to higher consumption of energy and the creation of heat islands is the best example of this matter (Azizi, 2004).

One solution to reduce such problems relates to using clean energies. Solar energy is a safe and more suitable supplying energy resource of current era, and has been used by humans in different ways. Because of energy crisis and destructive effects of fossil fuels in recent years, people have welcomed using renewable energies such as solar energy in order to decrease and save energy, control energy supply and demand and decrease polluting gases.

* Corresponding author email: Faramarzhadavi@gmail.com

Since the start of human life on earth, construction of buildings which are compatible with geography and climate of the region have always been considered of high importance. So from that time, attempts were based on creating climate-friendly buildings to achieve suitable heat condition through using natural materials and proper orientation of building. According to the views of Jiovani and Kenia, climate variety is the result of five important factors including: solar radiation, temperature, humidity, rainfall and wind. Solar radiation is the most important factor in the climate of each region (Ghiabekaloo, 2014). In cold climates, the most solar energy should be achieved, so the buildings are constructed in a way that they could absorb solar energy during the year. While in tropical climates, the building orientation should be in a way that annually reached solar radiation of its external walls fall to its lowest level.

RESEARCH BACKGROUND

There are high amount of scientific activities in this area. Victore and Al Dar Olgyay (1973) investigated the relationship between relative humidity, temperature and human thermal comfort, and presented human environmental comfort table. Parouch Giooni (1976) completed his work by investigating variables such as relative humidity, vapor pressure, dry and wet temperature, and he identified human comfort zone in resting position, followed by the amount of effectiveness of construction in supplying human bioclimatic needs. Then he presented psychometric charts (Ghobadian & Feiz, 2001). Karl Mahani (1971) tried to develop six dryness and wetness indices based on day and night temperature, humidity group, monthly temperature change, and day and night comfort zone. He presented the characteristics of buildings climate design in accordance to these indices (Kasmaee, 2005). In Iran, also, various studies has been carried out in relate to designing bioclimatic division maps using Köppen method (Adl, 1960), Iran's climate divisions map using Olgyay method (Riazi, 2009), Iran's climatic zoning using Mahani method (Kasmaee, 2005 & 1993), and Iran's human bioclimatic maps using Terjung methods (Kaviani, 1993). Few studies have been done in relate with the impact of solar radiation angle on the amount of energy which is absorbed by buildings walls in warm and cold months. Alikhani investigated the role of weather on designing houses in Tabriz, through his article. By considering climatic factors, like solar energy, he presented various methods of climate building design in Tabriz (Alikhani, 1995). In another article, Heidari et al. evaluated Zanjan human bio-climate, based on Gusinsky, Solianinuf, Karimi, Khosh Akhlagh, Ambreje and Ivanof methods. Then they suggested some methods for designing and constructing buildings based on human comfort conditions -using Terjung, Beaker and Mahani indices- and localizing building bioclimatic chart (Heidari et al., 2012). Barzegar and Heidari investigated the impact of solar radiation of building's shell on domestic energy consumption based on buildings orientation in Shiraz. The results of this research showed that houses with suitable orientation (mostly south-east or north-west) had proper conditions regarding to energy consumption and supply (Barzegar & Heidari, 2013) and (Barzegar et al., 2012). Santos et al. investigated the effect of solar orientation in energy consumption for climate office building located in the city of Santamari (Santos et al., 2012). Lashkari et al. investigated optimal building orientation in Ahvaz based on climate. According to their study, the most energy intake in vertical surfaces is for 15 degrees east and 30 degrees south-east. They also suggested buildings to be constructed in the optimal orientation of 45 degrees, or acceptable orientations of 30 or +15 degrees of north from south in Ahvaz climate (Lashkari et al., 2011). Hossein Abadi et al., investigated the climate design of residential buildings in Sabzevar with an emphasis on orientation and depth of shelter, and showed that the orientation of 15 and 30 degrees east for one sided buildings, and +165 and -15 degrees from north to south for two-sided buildings, were the best orientations in the case of solar radiation based houses in Sabzevar (Hossein Abadi et al., 2012).

Fossil fuels consumption is very high in Zanjan. For example, the gas usage in 2010 was 5.3 million square meters, and the electricity consumption in 2009 was 938444216 kilo watts (http:.www.zedc.ir). In Zanjan, there has not been any especial study on investigating the impact of radiation angle and orientation on building's energy intake. Objective of this research is to determine the optimal orientation, of Zanjan's buildings, through investigating the energy intake of walls' vertical surfaces. So it is necessary to carry out this research and determine the best orientations for buildings in Zanjan cold climate in order to have the most solar energy intake in cold months of the year.

INTRODUCING ZANJAN

Zanjan is located in north-west of Iran, at the end of Zanjan plain. It lies between two parallel mountain ranges: Soltanieh and Tarom. It is located on the intersection point of southern foothills alluvial fan, in Tarom Mountains, and "Zanjan Chai" river terraces. According to Dr. Ganji climatic divisions, Zanjan city is in cold climate (western mountains) with the abbreviation sign of «Cf'''a» .This city has cold and dry climate with cold winters and mild summers. There is high fluctuation of temperature during day and night, low weather humidity and heavy snow fall. Air concentration in this region is low, and this fact decreases natural air ventilation. Zanjan also faces south slopes, and because of topographical conditions of the region, it has been expanded towards west, east and north (Zamani, 2012).

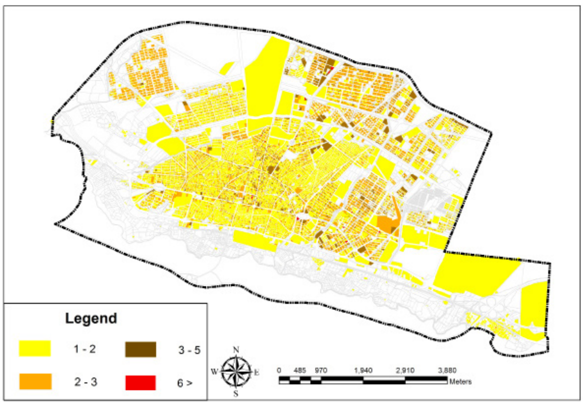
Table 1. Zanjan Geographical Characteristics

No	Index	Amount	No	Index	Amount
1	Sea Level (Meters)	1663	10	Sunshine	2838
2	Longitude	48° 19	11	Total Annual Rainfall (mm)	329.1
3	Latitude	36° 35	12	Population (in year 2006)	349713
4	Average air pressure (10^2 Pascal)	1014.1	13	Families (in year 2006)	89829
5	Average Annual Temperature (Celsius Degree)	11.5	14	Population Density (Person per km^2)	5828.55
6	Average Relative Humidity	5.42	15	Residential Units Numbers	72378
7	Average Wind Speed (m.s)	3.7	16	Residential Units Density (Person Per Unit)	4.8
8	Average Annual Solar Radiation on Vertical Surface (kwh.m^2)	3900	17	Family is Each Residential Unit	1.2
9	Wind Orientation	Eastern	18	Area (km^2)	60

(Zanjan Province General Census of Population and Housing, 2006; Zanjan Weather Almanac 1996-2006).

In Zanjan, the number of 1 to 2 floors apartments are 71083, 3 to 5 floor apartments are 2634, while and 6 floor apartments and higher are 32. Apartments with concrete materials and structure are 910, with brick and iron structure are 22201, with steel structure is 14940, and with brick and wood structure are 244. Wall thickness of the houses with concrete and steel structure is less than 20 cm, and it is made up of concrete and ceramic blocks. The thickness of these walls with brick, iron and brick structure is more than 40 cm, and it is made up of pressed brick or mud brick. And their heat transfer coefficient is 1.97w.m^2k. Roof thickness is generally more than 30 cm and the heat transfer coefficient of these kinds of roofs is 1.37w.m^2k.

Fig. 1. Distribution of Residential Units in Zanjan City based on Floor Numbers



RESEARCH METHOD

The research method was retrospective panel and survey. In this method through investigating the city structural characteristics based on existing records and evidence, and observing existing condition, a comparison is made with the past and then the derived data will be analyzed. After that, according to collected data and information, the role of determined parameters will be evaluated in these changes. So in order to study the optimal climatic conditions of Zanjan buildings, the statistics related to climatic factors such as average of the most and the lowest temperature, average of the lowest

and the most relative humidity, frost, rainfall, radiation, wind speed and orientation for a period of 40 years (from 1969 to 2009) was collected from Zanjan Synoptic Center. Then the orientation and height of sun was extracted by using Q-BASIC. The amount of solar radiation on vertical surfaces of walls in various angles was calculated using law of cosines, and then the dominant bioclimatic types of cold and warm period were determined. Finally, figures and diagrams were drawn by using EXCEL software.

DATA ANALYSIS

Since earth rotation around the sun changes, different seasons of the year are different in solar radiation angle; as a result energy intake is different during the year. Therefore, a building's orientation which is affected by the amount of solar radiation on its walls changes during the year and various hours. The importance of solar radiation in climatic design depends on climate and the seasons. In warm conditions, the lowest solar energy is needed and the building should be directed in a way that the lowest sun light is taken by it. On the other hand, in cold conditions, the orientation of a building should be in a way that it took the most solar radiation, preventing the sun ray from reaching the interior spaces. (Of course this fact should be taken into account that the impact of a building orientation on interior warmth conditions depends on the building design and characteristics, and it may be possible through choosing dark external surfaces, orientation impact reaches to its most level. Because white surface will reflect most energy intake. So it can be concluded that using different colors in the external surfaces of a building can control the thermal impacts of solar radiation.) Considering that cold months in Zanjan are more than warm months, the objective of the research is determining the optimal orientation of a building for taking the most solar energy in cold season of Zanjan. In this optimal orientation the sun will shine directly to the main frontage of the building.

Table 2 shows the two-hour changes in Zanjan which is extracted from Zanjan Synoptic center. Using the two-hour changes in a month and human thermal comfort zone, determines the months which need warmth or coldness. Considering that the temperature of human thermal comfort zone is between 18 to 22 degrees, Zanjan buildings need to absorb solar energy most of the days.

Table 2. Zanjan Temperature Changes in an Hour in a Two-hour Interval (Monthly Average)

Hour	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2	-6	-6	-1.5	4	8	12	15.5	17	13.5	8.5	4	-1.5
4	-6.5	-7	-2	3	7	11	15	16	12	7.5	2.5	-2.5
6	-5.5	-7.5	-2.5	2.5	6.5	10	14	15	11.5	6.5	2	-3
8	-1.5	-6.5	-1.5	3.5	7.5	11.5	15.5	16.5	12.5	8.5	3.5	-2
10	1.5	-1.5	3.5	9.5	14.5	19.5	24	25	20.5	15.5	9.5	3
12	3	1.5	6.5	13.5	18.5	24.5	29	29.5	25	20	12.5	5.5
14	2	3	8	25	20.5	26.5	31.5	32	27	22.5	14.5	7.5
16	-0.5	2	7.5	14	19.5	25.5	30	30.5	26	21	13.5	6.5
18	-2.5	-0.5	4.5	11	16	21.5	26	27	22.5	17.5	10.5	4
20	-4	-3	1.5	8	12.5	17	21.5	22.5	18	13.5	7.5	1.5
22	-5	-4.5	0.5	6.5	10.5	15	20	20.5	16	11.5	6	0

Zanjan Meteorology Center

There are different calculating methods, like Olgyay Diagram, to calculate solar heat energy on different surfaces. This research has chosen the below formula for this intention:

(1) $I_s = I_N \cos\theta$

In the above formula:

In the above formula the amount of I_N would be calculated through the below formula which is suggested by Stiphenso (Kasmaee, 1993).

(2) $I_{DN} = I^0 \exp({}^{-a}/\sinh)$

In this formula:

I_{DN} = heat resulted from direct and vertical solar radiation

I^0 = solar constant

a= extinction coefficient

h= angle of solar radiation

Also θ is the angle of intersection of sun and vertical line (on a wall) which will be determined through spherical cosine equation (Watson & Labs, 1983).

I_S= Radiation on surface (BTU.H. FT [2])

I_N= Solar radiation over vertical surfaces (BTU.H. FT [2])

θ= the angle between sun radius and vertical line on surface

In the above formula the amount of would be calculated through the below formula which is suggested by Stiphenso (Kasmaee, 1999).

$\cos(\theta)= \cos(B) \ (\cos(\Psi)-\cos(\varnothing))$

In this formula:

B= shine angle

∅ = radiation angle

Ψ= wall angle in a clockwise direction from the north, measured in degree

Using the above mentioned equations determine the amount of energy intake on vertical surfaces, for various months, in 24 geographical orientation for Zanjan.

Table 3 shows total radiated energy on vertical surfaces in different month of the whole year and.

Table 3. Energy Intake on Zanjan Vertical Surface (BTU.H. FT²)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
North	-	-	-	-	-	-	-	-	-	-	-	-
+15	-	-	-	18.12	3.71	82.31	73.7	81.3	73.4	11.69	-	-
+30	0.91	2.17	04.17	55.83	213.74	261.2	264	269	221	75.88	15.86	-
+45	92.24	87.102	46.105	42.210	378.9	452.7	458	459	415	187.6	108.4	28.9
+60	46.112	7.254	73.250	73.377	550.7	628.7	640	642	625	329.2	261.9	134.7
+75	33.262	20.459	37.430	09.548	708.87	769.2	784	791	773	471.8	251.5	299.1
East	63.456	13.690	620	39.698	825.23	856.3	865	879	895	600.3	653	503.3
+105	27.700	69.933	1.829	8.843	903.29	874.4	902	983	989	718.1	868.9	738.2
+120	62.953	2.1176	1.1013	7.953	926.45	893	887	958	1014	802.8	1074.5	979.4
+135	8.1203	7.1400	7.1193	3.1018	914.94	818.7	806	873	1006	949.8	1263.1	1228.1
+150	6.1449	3.1606	1350	7.1070	857.98	719.3	685	748	841	900.5	1434.7	1473
+165	1.1623	7.1769	9.1487	6.1114	783.62	282.8	538	602	863	931	1493	1635
South	1.1682	1861	9.1544	3.1145	736.65	479.8	434	511	746	1122.7	1714	1696
-165	1.1623	7.1769	9.1487	6.1114	783.62	282.8	538	602	863	931	1493	1635
-150	6.1449	3.1606	1350	7.1070	857.98	719.3	685	748	841	900.5	1434.7	1473
-135	8.1203	7.1400	7.1193	3.1018	914.94	818.7	806	873	1006	949.8	1263.1	1228.1
-120	62.953	2.1176	1.1013	7.953	926.45	893	887	958	1014	802.8	1074.5	979.4
-105	27.700	69.933	1.829	8.843	903.29	874.4	902	983	989	718.1	868.9	738.2
West	63.465	13.690	620	39.698	825.23	856.3	865	879	895	600.3	653	503.3
-75	33.262	20.459	37.430	09.548	708.87	769.2	784	791	773	471.8	251.5	299.1
-60	46.112	7.254	73.250	73.377	550.7	628.7	640	642	625	329.2	261.9	134.7
-45	92.24	87.102	46.105	42.210	378.9	452.7	458	459	415	187.6	108.4	28.9
-30	0.91	2.17	04.17	55.83	213.74	261.2	264	269	221	75.88	15.86	-
-15	-	-	-	18.12	71.3	82.31	73.7	81.3	73.4	11.69	-	-

The calculations of this table are theoretical. In order to take a realistic approach towards them, these amounts will be multiplied in the coefficient of different months to calculate real energy level on vertical walls (In table 4).

Table 4. Energy Intake Amounts on Vertical Surfaces in Zanjan, with Coefficient Consideration (BTU.H. FT²)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
North	-	-	-	-	-	-	-	-	-	-	-	-
+15	-	-	-	6.57	43.51	63.37	56.77	49.61	50.68	8.88	-	-
+30	0.43	8.94	9.54	45.11	130.38	201.12	203.6	163.85	152.77	57.66	9.51	-
+45	11.96	53.49	59.05	113.62	231.14	348.6	352.59	280.07	286.28	142.59	65.06	14.45
+60	53.98	132.44	140.4	203.97	335.94	484.13	492.45	391.91	431.43	250.22	157.15	67.35
+75	125.91	238.69	241	295.96	432.41	592.34	603.83	482.46	533.43	358.6	150.91	149.59
East	223.5	358.86	347.21	377.13	503.39	659.4	666.28	536.03	617.36	456.27	391.98	251.69
+105	336.12	485.51	464.33	455.66	551	673.54	695.04	599.89	682.58	545.8	521.94	369.12
+120	457.73	611.68	567.33	515.04	565.13	687.66	683.25	584.56	699.68	610.12	644.72	489.72
+135	557.83	728.4	668.47	549.89	558.11	630.42	621.24	532.54	693.88	721.87	757.86	614.06
+150	695.82	835.28	756.05	578.19	523.36	553.89	527.26	456.33	580.12	684.37	860.83	736.5
+165	779.09	920.27	833.26	601.89	478	217.8	414.36	367.22	595.44	707.61	863.43	817.65
South	807.41	967.76	865.16	618.49	449.35	369.48	334.31	312.1	514.86	853.31	1028.4	848.22
-165	779.09	920.27	833.26	601.89	478	217.8	414.36	367.22	595.44	707.61	863.43	817.65
-150	695.82	835.28	756.05	578.19	523.36	553.89	527.26	456.33	580.12	684.37	860.83	736.5
-135	557.83	728.4	668.47	549.89	558.11	630.42	621.24	532.54	693.88	721.87	757.86	614.06
-120	457.73	611.68	567.33	515.04	565.13	687.66	683.25	584.56	699.68	610.12	644.72	489.72
-105	336.12	485.51	464.33	455.66	551	673.54	695.04	599.89	682.58	545.8	521.94	369.12
West	223.5	358.86	347.21	377.13	503.39	659.4	666.28	536.03	617.36	456.27	391.98	251.69
-75	125.91	238.69	241	295.96	432.41	592.34	603.83	482.46	533.43	358.6	150.91	149.59
-60	53.98	132.44	140.4	203.97	335.94	484.13	492.45	391.91	431.43	250.22	157.15	67.35
-45	11.96	53.49	59.05	113.62	231.14	348.6	352.59	280.07	286.28	142.59	65.06	14.45
-30	0.43	8.94	9.54	45.11	130.38	201.12	203.6	163.85	152.77	57.66	9.51	-
-15	-	-	-	6.57	43.51	63.37	56.77	49.61	50.68	8.88	-	-

Then the results of table 3 and 4 were used to measure the energy intake on vertical surfaces for warm and cold periods, and the results are presented separately in tables 6 and 7. In table 5, the average of sunny hours and their percentage from day and night are calculated.

Table 5. The Percentage of Sunny Hours in Zanjan (Zanjan Meteorology Center)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Average	-	-	-	-	-	-	-	-	-	-	-	-
Day Length in Zanjan Latitude	9.59	10.32	11.43	12.6	13.74	14.44	14.44	13.74	12.64	11.39	10.28	9.57
Average of Sunny Hours	4.61	5.38	6.44	6.83	8.40	11.15	11.55	11.31	10.61	8.77	6.19	4.84
Percentage of Sunny Hours in a Day	%48	%52.3	%54.3	%54.2	%61.1	%77.2	%77.2	%82.3	%83.9	%76.9	%60.2	%50.5

Table 6. Energy Intake on Vertical Surfaces in Zanjan, Considering Coefficient in Cold Period (BTU.H. FT²)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
North	-	-	-	-	-	-	-	-	-	-	-	-
+15	-	-	-	6.57	43.51	63.37	56.77	43.12	50.68	8.88	-	-
+30	0.43	8.94	9.54	45.11	130.38	201.12	184.68	121.37	131.47	57.66	9.51	-
+45	11.96	53.49	59.05	113.62	231.14	348.6	306.31	191.18	210.02	142.59	65.06	14.45
+60	53.98	132.44	140.4	203.97	335.94	484.13	408.06	249.45	271.09	250.22	157.15	67.35
+75	125.91	238.69	241	295.96	432.41	592.34	483.42	291.23	311.73	343.14	150.91	149.59
East	223.5	358.86	347.21	377.13	503.39	659.4	515.63	312.72	33.35	411.61	391.8	251.69
+105	336.12	458.51	464.33	455.66	551	658.55	527.88	310.52	331.36	451.12	521.94	369.12
+120	457.73	611.68	567.33	515.04	565.13	657.68	496.88	289.01	305.24	461.99	644.72	489.72
+135	557.83	728.4	668.47	549.89	558.11	587.59	432.58	318.72	257.85	508.34	758.86	614.06
+150	695.82	835.28	756.05	578.19	515.02	479.1	336.24	187.73	195.51	389.16	860.83	736.5
+165	779.09	920.27	833.26	601.89	435.02	116.85	198.76	172.93	117.32	310.88	863.43	817.65
South	807.41	967.76	865.16	618.49	359	167.61	83.26	37.48	26.09	343.58	1028.4	848.22
-165	779.09	920.27	833.26	601.89	435.02	116.85	198.76	172.93	117.32	310.88	863.43	817.65
-150	695.82	835.28	756.05	578.19	515.02	479.1	336.24	187.73	195.51	389.16	860.83	736.5
-135	557.83	728.4	668.47	549.89	558.11	587.59	432.58	318.72	257.85	508.34	758.86	614.06
-120	457.73	611.68	567.33	515.04	565.13	657.68	496.88	289.01	305.24	461.99	644.72	489.72
-105	336.12	458.51	464.33	455.66	551	658.55	527.88	310.52	331.36	451.12	521.94	369.12
West	223.5	358.86	347.21	377.13	503.39	659.4	515.63	312.72	33.35	411.61	391.8	251.69
-75	125.91	238.69	241	295.96	432.41	592.34	483.42	291.23	311.73	343.14	150.91	149.59
-60	53.98	132.44	140.4	203.97	335.94	484.13	408.06	249.45	271.09	250.22	157.15	67.35
-45	11.96	53.49	59.05	113.62	231.14	348.6	306.31	191.18	210.02	142.59	65.06	14.45
-30	0.43	8.94	9.54	45.11	130.38	201.12	184.68	121.37	131.47	57.66	9.51	-
-15	-	-	-	6.57	43.51	63.37	56.77	43.12	50.68	8.88	-	-

Table 7. Energy Intake on Vertical Surfaces in Zanjan, Considering Coefficient in Hot Period (BTU.H. FT²)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
North	-	-	-	-	-	-	-	-	-	-	-	-
+15	-	-	-	-	-	-	-	6.48	-	-	-	-
+30	-	-	-	-	-	-	18.91	42.48	21.3	-	-	-
+45	-	-	-	-	-	-	46.27	88.89	76.25	-	-	-
+60	-	-	-	-	-	-	84.38	142.45	160.23	-	-	-
+75	-	-	-	-	-	-	120.4	191.22	221.69	15.45	-	-
East	-	-	-	-	-	-	143.72	223.3	284	44.65	-	-
+105	-	-	-	-	-	14.99	167.15	289.37	351.22	94.68	-	-
+120	-	-	-	-	-	29.99	186.37	295.54	394.43	148.12	-	-
+135	-	-	-	-	-	42.82	188.65	213.82	436.03	213.53	-	-
+150	-	-	-	-	8.33	74.79	191.02	268.59	384.61	295.2	-	-
+165	-	-	-	-	42.98	114.95	194.81	194.28	478.11	396.72	-	-

South	-	-	-	-	95.22	201.87	250.9	274.61	488.76	509.73	-	-
-165	-	-	-	-	42.98	114.95	194.81	194.28	478.11	396.72	-	-
-150	-	-	-	-	8.33	74.79	191.02	268.59	384.61	295.2	-	-
-135	-	-	-	-	-	42.82	188.65	213.82	436.03	213.53	-	-
-120	-	-	-	-	-	29.99	186.37	295.54	394.43	148.12	-	-
-105	-	-	-	-	-	14.99	167.15	289.37	351.22	94.68	-	-
West	-	-	-	-	-	-	143.72	223.3	284	44.65	-	-
-75	-	-	-	-	-	-	120.4	191.22	221.69	15.45	-	-
-60	-	-	-	-	-	-	84.38	142.45	160.23	-	-	-
-45	-	-	-	-	-	-	46.27	88.89	76.25	-	-	-
-30	-	-	-	-	-	-	18.91	42.48	21.3	-	-	-
-15	-	-	-	-	-	-	-	6.48	-	-	-	-

FINDINGS

Regarding to the results of table 6 and 7, the level of energy on vertical walls in warm and cold periods are calculated and the difference between them is presented in table 8. Based on these differences, the optimal

Table 8. Determining the Differences of Cold and Hot Period and Prioritizing

Orientation	Hot	Cold	Difference	Priority
North	-266.42	0	0	13th
15 degree	6.48	272.9	266.42	12th
30 degree	82.69	900.21	817.52	11th
45 degree	211.41	1747.47	1536.06	10th
60 degree	387.06	2754.12	2367.06	9th
75 degree	548.76	3656.33	3107.57	8th
90 degree	695.67	4724.29	4064.62	7th
105 degree	656.41	5436.11	4780	5th
120 degree	1054.45	6062.15	5007.7	3th
135 degree	1094.85	6540.7	5445.85	1ST
150 degree	1222.54	6565.43	5342.89	2nd
165 degree	1421.85	6176.35	4754.5	4th
South	1821.14	6152.47	4331.3	6th
165 degree	1421.85	6176.35	4754.5	4th
150 degree	1222.54	6565.43	5342.89	2nd
135degree	1094.85	6540.7	5445.85	1st
120 degree	1054.45	6062.15	5007.7	3rd
105 degree	656.41	5436.11	4780	5th
90 degree	695.67	4724.29	4064.62	7th
75 degree	548.76	3656.33	3107.57	8th
60 degree	387.06	2754.12	2367.06	9th
45 degree	211.41	1747.47	1536.06	10th
30 degree	82.69	900.21	817.52	11th
15 degree	6.48	272.9	266.42	12th
North	0	0	0	13th

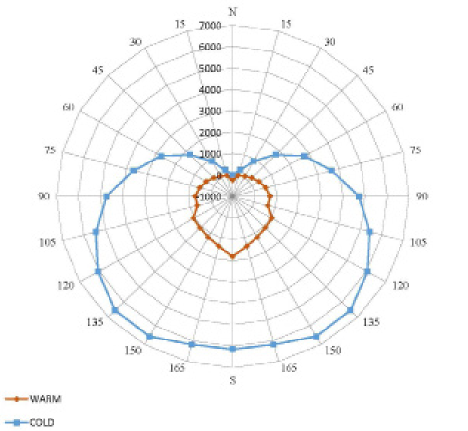


Fig. 2. The Amount of Solar Radiation in All Orientations in the Whole Year

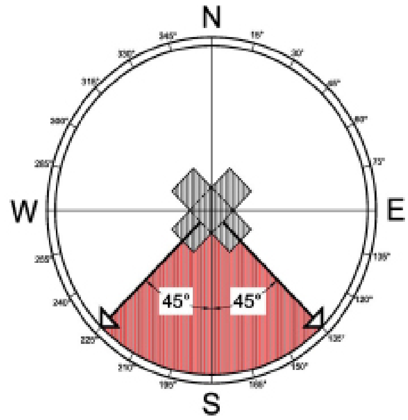


Fig. 3. The Best Orientation for the Buildings in Zanjan City

As it can be seen in table 8, solar energy intake on different surfaces in eastern and western orientations are symmetric through whole year. The most energy intake in cold and warm months is related to +150 south-east and -150 south-west; and the lowest in cold and warm months is related to +15 and -15 north-east and west.

But these have different functions orientations in relation to solar energy intake during warm and cold periods. Orientations of +135 south-east and -135 south-west have the biggest differences in energy intake of warm and cold months. According to Figure 1, southern orientations have the most amount of energy in warm periods and northern orientations have the least amount in cold period. So regarding to the determined relation, south-east and south-west orientations are optimal to choose as the best orientations for buildings to take the most solar energy. And orientations of 15-45 north-east and west are among the acceptable orientations for not taking energy. Based on the results of table 8 and figure 1, two orientations with Azimouth angle 135 and 225 degrees are the best orientations for buildings in Zanjan, in order to get the most solar energy on vertical surfaces.

DISCUSSION AND CONCLUSION

As Zanjan is located in high geographical latitude (36 degrees north), its height is 1600 meters from sea level, it has longer cold and shorter warm periods, it has especial geographical situation. As it is very important in Zanjan that buildings take the most solar energy in cold seasons, they should be built in a way that they can absorb the most energy on their vertical surfaces. So buildings' orientation should be in a way that absorb the most energy in cold seasons and the lowest energy in warm seasons. In this research, in order to calculate sun thermal energy on various surfaces, law of cosines was used. By using this law, the solar energy intake on vertical surface, for various months and in 24 geographical orientations of Zanjan, was calculated and theoretical levels of solar energy were achieved. Then, through using sunny hours driven from Zanjan Synoptic center and dividing them to day length in each month, sunny hours' percentage of each month was achieved. In order to define the real level of solar energy, theoretical levels of solar energy in each month were divided by sunny hours' percentage of that month. Finally, after calculating the energy intake on vertical surfaces in cold and warm months of the year, the below results were achieved:

- Vertical surfaces with the orientations of +150 and -150 south-west absorb the most amount of sun light and surfaces with the orientations of +15 and -15 north-east and west, achieve the lowest energy in cold and warm months of the year.
- The highest difference of vertical surfaces' radiated energy is +135 south-east and – 135 south-west in warm and cold periods.
- To absorb the most solar energy in Zanjan, best priority of buildings' orientation is Azimouth angle of 135 and 225 degrees.

REFRENCES

Adl, A .H. (1960). *Iran's Climate and Plants Divisions*, Tehran University Publications.

Alijani, B. (1995). New Approach in Using Weather in Iran's Development and Resources Management (Role Of Weather In Housing Design), *Geographical Research Journal*, (35).

Azizi, Gh. (2004). *Climate Change*, Ghomes Publishers.

Barzegar, Z., & Heidari, SH. (2013). Investigating the Impact of Absorbed Solar Radiation of Buildings on Domestic Energy Consumption, *HONAR-HA-YE-ZIBA,* 18 (1), spring.

Barzegar, Z., & Heydari, SH. (2012). Evaluation of the Effect of Building Orientation on Achieved Solar Radiation-A NE-SW Orientated Case of Urban Residence in Semi-Arid Climate, *International Journal of Architectural Engineering & Urban Planning,* 22 (2).

Ghiabekloo, Z. (2014). *Arranging Environmental Conditions*, Jahad Daneshgahi Publications, San'ati Amir Kabir, (8th ed).

Heidari, M., Pourmohammadi, M., Jamali, F., & Lotfi, F. (2012). Evaluating Human Climate in Zanjan and Its Role in Housing Design, *Journal of New Approaches in Human Geography*, 4(2), spring.

Hossein Abadi, S., Lashkari, H., & Salmani Moghadam, M. (2012). Climate Design of Buildings in Sabzevar with an Emphasis on Orientation and Shelter Depth, *Geography and Development*, (27), summer.

http://nigc-zanjan.blogfa.com

http://www.zedc.ir

Kasmaee, M. (1993). *Iran's Climatic Divisions-Housing and Residential Environment*, Tehran: Building and Housing Research Center Publications.

Kasmaee, M. (2005). *Climate and Architecture,* Iran House Making Company Publications.

Kaviani, M. (1993). Investigating Iran's Human Climate, *Geographical Research Journal*, (28).

Lashkari, H., Mouzemi, S., Salki, H., & Lotfi, K. (2011). Optimizing Buildings Orientation in Ahvaz Based on Climate, *Natural Geography*, 4 (12), summer.

Najafi, J. (2003). *Investigating and Analyzing Kermanshah Weather with an Emphasis on Harmonizing Schools Architectural Pattern*, Master Dissertation, Shahid Beheshti University.

Pourkhadem Namin, Z. (2003). *The Role of Climate in the Design and Development of Buildings in Ardebil,* Master dissertation, Shahid Beheshti University.

Razjouyan, M. (1988). *Comfort by Climate Friendly Architecture*, Tehran: Shahid Beheshti University Publications.

Razjouyan, M. (2000). *Comfort in Wind*, Shahid Beheshti University Publications.

Riazi, J. (2009). The Principles of Calculating Thermal Transmission in Buildings Components, *Building and Housing Research Center,* 211.

Santos, J. P., & Soares, R. M. D. (2012).The Effect of Solar Orientation in Energy Consumption for Climate Office Building Located in the City of Santamaria, *28th Conference Opportunities, Limits & Needs towards an Environmentally Responsible Architecture*, Lima Peru.

Tavasoli, M. (1981). *Constructing Cities and Buildings in Iran's Warm and Dry Climate*, Fine Arts Faculty, Tehran University.

Zamani, M. (2012). *Investigating Zanjan's Geomorphological Capacities and Limitations Relating to Safety and Development*, Ph.D. Dissertation, Islamic Azad University, Science and Research Branch.