JOURNAL OF CURRENT RESEARCH IN SCIENCE (ISSN 2322-5009)
CODEN (USA): JCRSDJ
2014, Vol. 2, No. 3, pp: 332-339
Available at www.jcrs010.com

ORIGINAL ARTICLE

EVALUATION OF THERMAL COMFORT INDICES OF BUILDINGS IN MASHHAD CITY, IRAN

Saeid Kamyabi*, Ali Gholamzadehdoab, Afra Ahmdi
Department Of Geography, College Of Human Science, Semnan Branch, Islamic Azad University, Semnan, Iran

ABSTRACT: One of the most important human factors that impact on housing needs and climatic characteristics, weather conditions, the So that the effect of these elements, and feedback on how architecture is inevitable and the importance of climate and its effect on human life is not hidden from anyone. The purpose of this paper to identify and evaluate the thermal comfort indices and is consistent with climatic factors. In this paper, the climatologically statistics for the past 12 years during a climatic period (2000-2012) was my goal, to provide statistics on new climate and the occurrence of the Climate Research Center, Mashhad, visiting, and statistical yearbook weather Meteorological Organization in Mashhad and the site has been getting non-attendance. The research is descriptive method with field work and then using thermal indices like Guni, Oleg, Mahan, Trjong, Baiker and ... Architecture compatible with the climatic conditions provided for in Mashhad Finally, suggestions for the design of residential space, including the physical form of the building, the windows and ... Etc. are presented.
KEYWORD: Climate, architecture, thermal comfort indices, Mashhad city.

INTRODUCTION

Studying the effect of climate on housing and people's comfort is not a new issue and dated back to 400 B.C. designing compatible with climate means keeping microclimatic situation of house in comfort range (Farajzade and Lashkari, 2002). Therefore it is necessary to know the climate in order to achieve the compatibility with that. The main purpose of architecture is representing a shelter which consists of different elements that meaningfully create our physical, social, and aesthetic climates which we live. In nowadays housing with low quality materials replaced with high quality materials that in this type of housing there isn't enough attention to climatic situation so results in wasting energy and loosing comfort; so considering climate in designing and returning to rational and scientific architecture that is compatible with climate can solve the problem. One of the important factors that affect housing is climatic characteristics and weather condition. Researches on climatic compatibility in Iran mostly related to bio-climatic zoning and not to climatic compatibility of buildings (Moradi, 2005), Therefore comfort neglected in housing so as a result in summers we feel hot and in winters we feel cold in our houses thus it is necessary to evaluate the thermal comfort of inhabitants and this is the reason to this research to be done. People living in naturally ventilated unconditioned buildings usually have more tolerance to wide change in the temperature of a summer day. In addition to the geographically-impacted disparity in the perception of comfort, there are other factors that can impact the human sensation of comfort. Macpherson (Emmanuel, 2005), specified six factors that can impact the sensation of comfort which are air speed, mean radiant temperature (MRT), metabolic rate, clothing level in addition to temperature and humidity In 1986, a commission consists of architects and meteorologists formed in Geneva in order to evaluate the climatology of building. Also, Johnson, (2002), mentioned choosing housing location and believes that local climatic situation is important in comfort. (Kaviani, 2004), in our country researches had done that we can mention climatic classification of Tousi, (2003) and also the first climatic classification in order to use in building construction had done by Jahansson, (2006) according to Olgy method. Alijani, (1994) declared that Mashhad is the second largest city in Iran. It is located 850 kilometers (530 mi) east of Tehran, at the center of the Razavi Khorasan Province close to the borders of Afghanistan and Turkmenistan. Its population was 2,427,316 at the 2006 population census. It was a major oasis along the ancient Silk Road connecting with Merv in the East. The city is located at 36.20º North latitude and 59.35º East longitude, in the valley of the Kashaf River near Turkmenistan, between the two mountain ranges of Binalood and Hezar-masjed. The city benefits from the proximity of

Corresponding Author: Saeid Kamyabi, Department Of Geography, College Of Human Science, Semnan Branch, Islamic Azad University, Semnan, Iran. **E-mail:** saeidkamyabi@gmail.com

the mountains, having cool winters, pleasant springs, mild summers, and beautiful autumns. It is only about 250 km (160 mi) from Ashgabat, Turkmenistan. In Mashhad city these researches have been conducted: Mansouri, (1996), evaluated climatic statistics in Khorasan province synoptically and 8 weather stations data in last 30 years. Salamat, (2001) analyzed climatic classification of Khorasan province in Mashhad by daily data of at least 21 weather stations. Alizadeh, (2002), according to daily weather data of at least 15 stations in Khorasan province evaluate the first occurrence of frost period in fall and last frost period in spring and length of period without frost. Bani, (2004), in his doctorate thesis analyzed and forecasted statistical climate of Khorasn. Samadi, (2006), in his thesis studied the effective synoptic systems in Khosran Razavi province. Babaean, (2002), in Nivar journal evaluated Mashhad's climate.

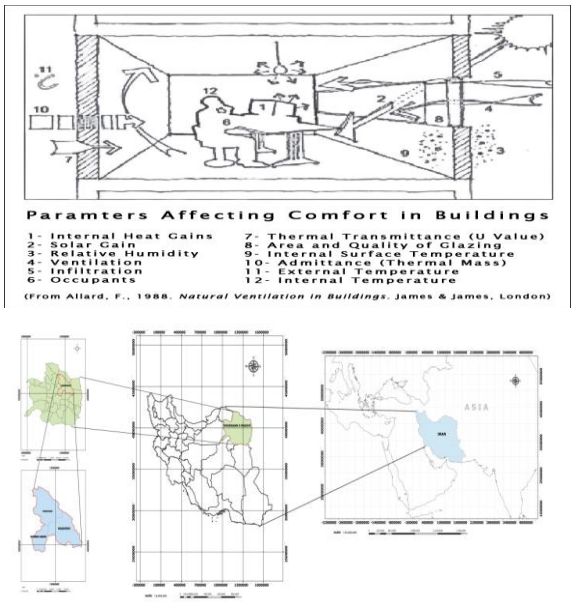

Figure 1: Case study situation

As people stay at their home for considerable time during their life, comfort is necessary at home. Designing a building according to climatic characteristics of its location can create comfortable situation without using cooling and heating machines. This research has been conducted in Mashhad that located in warm and dry area. The purposes of climatic studies are creating comfortable situations with using less fossil energy. This paper by studying the effects of climate on building and man's comfort tried to suggest appropriate solutions for Mashhad. Therefore, in order to reach this goal, after being familiar with each climatic index and its effects on housing and comfort we will give some suggestions.

1.1. Questions of Research

1- How we calculate thermal comfort indices in Mashhad?
2- Which one of thermal comfort indices can help to design compatible with climate?
3- Do people consider architecture compatible with climate according to thermal comfort indices?
4- Can we reach to a comfort range in Mashhad without considering architecture compatible with climate?

1.2. Purposes of Research

Purpose of this paper is being familiar with thermal comfort indices in Mashhad and its effect on housing and creating good conditions for people that its result can be helpful for architects.

METHODS

Climatic indices with evaluating parameters of atmosphere in long terms can determine climatic condition of each region. Therefore first step in this research will be finding long term parameters and statistics from weather stations. These parameters are daily and monthly precipitation, minimum and maximum temperature, absolute minimum and maximum temperature and daily and monthly averages in last 12 years (2000-2012) and also radiation and direction and wind speed, humidity, dominant wind, Mashhad's wind roses which had been evaluated and then ombrothermic, Dulgi and Mahani charts created. Method of research is analytic, descriptive and combination of field operation. I personally visit institute of Mashhad climatology and Mashhad metrological organization and visit www.iranhydrology.com and www.weather.ir

Evaluation of thermal comfort indices has different methods and requires long term statistics of meteorology and its analysis so we can evaluate effects of climate on human's comfort by using bioclimatic indices.

2.1. Data analysis

Statistical chart of effective elements on last 12 years of architecture in Mashhad is given in table 1. This chart created in last 12 years (2000-2012) by information of Mashhad climatology institute. In order to find precipitation of March in 12 years, I add all march's precipitation in 12 year and then divided by 12. I did the same for temperature, relative humidity, dominant wind speed.

Chart 1: effective elements on last 12 years of architecture in Mashhad (2000-2012) source: writer

Month	Total precipitation in 12 years	Weather temperature			Relative humidity	Relative humidity		Dominant wind speed
		Average	Average minimum	Average maximum		hour 512/	hour 6/5	
March	41.24	14.37	8.25	20.45	59.45	48.17	80	4.95
April	28.2	20.64	13.84	27.41	48.8	38.4	67.4	5.12
May	4.14	25.26	17.85	32.70	31.12	24.5	45.5	5.83
June	2.25	27.72	20.58	35.21	27.70	22	39	6.44
July	.72	27.30	19.61	34.86	25.04	19.5	37.1	5.44
August	2.68	22.76	14.98	29.16	29.70	20.2	44.6	4.62
September	1.51	17.90	10.17	25.68	39.54	28.8	59.9	3.82
October	20.46	11.3	5.12	17.53	57.37	43.9	81	3.2
November	23.39	5.55	.42	10.64	69.58	56.9	91	2.32
December	24.49	2.62	-2.38	7.68	69.66	58	90	2.94
January	24.31	4.89	-.44	10.16	67.62	58.5	91.7	3.85
February	43.79	88	3.34	14.39	64.87	52	88.5	4.95
12 years	21.69	13.48	9.28	22.16	49.14	39.2	68.75	2.86

RESULTS

3.1. Domartin climatic classification

In order to determine Mashhad climatic condition according to Domartin climatic classification, we calculate as follow:

T= annual average temperature; P= annual average precipitation

Domartin coefficient $$D = \frac{P}{t + 10}$$

Domartin coefficient for period of 12 years $$D = \frac{218/8}{13/48 + 10} = 9/31 \rightarrow 5 < D < 10$$

According to Domartin index, Mashhad has arid climate.

3.2. Amberje climatic classification

Main structure of Amberje equation is dividing precipitation by temperature but instead of calculation average temperature in a year, it considers minimum and maximum of temperature.

$$Q = \frac{2000p}{M^2 - m^2}$$

$$Q = \frac{2000 \times 21/8/8}{(37/2 + 273)^2 - (-9/3 + 273)^2} = \frac{437600}{26686/35} = 16/39$$

According to Amberje index, Mashhad has arid & cold climate

Chart 2: results of Mashhad climatic classification

climate	Arid & cold
Plan type	compact
Materials type	High heat capacity and resistant to humidity Brick & cement
Roof type	flat
Building density	Compact with minimum external surface
direction	Should pass the warm sunshine in summers 25 East to 35 SE
form	Plan expansion in east, west axis
context	Compact with narrow alleys and high walls
Outside color	dark
Surface & number of windows	Small an few windows. No east-west windows if there are , with vertical sunshade
Connection to ground	Should consider the insulation
Wall	Thick walls in order to stop the entrance of heat
ground	Using hollow grounds because they are cool in summer
Building's volume	Cubic shapes with height of 2 floor
Plan form	Square form plan
Doors & windows type	Wooden because of low heat coefficient
Functional elements	Loggia in summer
Doors & windows	Vertical windows and should located on top parts
streets	East-west direction
underground	In hot season & cool weather
facing	Don't use smooth facing
plants	Leafy plants at room's side and landscaping & fountain
Shelter	High shelter on the roof overshadows on alley

Chart 3: Mashhad's classification in climatic classification source: writer

Classification system							city
Karimi (i)	Gorzenski (C)	Silianinoff (c)	Blor (Rain)	Ivanoff (i)	Amberj (Q2)	Domartin (i)	
Semi-arid with hot summers and cold winters	cold in winters and semi-arid to arid c =44/91	Arid C= 028	arid	Steppe i= 0.46	Arid cold 16.9	Arid 9.3	Mashhad

DISCUSSION

4.1. Climatic solutions

The most important factor in arid area is maximum day temperature and its fluctuation range. Absorbed amount of sunshine by walls is important factor that related to direction and color of wall. Choosing materials in this climate, also related to the size of the windows and quality of sunshades. If windows are small and sunshades are effective, heat absorbed by building will be the result of heat conductivity through walls so heat resistance of materials are more important that their heat capacity. In this situation light weight concrete with proper thickness in order to provide necessary QR according to climatic condition is appropriate material. If we use big windows and inappropriate sunshades, heat will be absorbed mostly through windows and light weight materials become warmer than heavy materials so in this situation heat capacity is more important than heat resistance. Brick and compact concrete with thickness of 20 to 40 cm can be proper for this condition.

Best wall types in these regions are compound walls that consist of insulation and heavy materials. If we use insulation and light color on the outside, absorption of solar energy will decrease and heavy materials will absorb the rest of the heat.

Generally proper materials to keep the house cool are: concrete walls with high heat capacity that their outside covered by insulation such as rock wool.

4.2. Buildings form and climate

Best form is a form that looses the least heat in winter and absorbs the least heat in summer from sun. So square plan is the best because with the most volume has the least surface. In Mashhad for of the buildings can expand on East-west axis. But according to summer situation building must be compact and cubic. By cutting off some parts of this cube and filling in the created cavity with shadow and cool air we can create a proper space in building (Razjooyan, 2009).

4.3. Combination of internal spaces

Rooms must be in south because they get more energy from sun in daylight. Direction of street according to wind direction and sun should be in a way that we use the most energy of sun in cold winter days. Dominant wind in cols season blows from North-East and South-East that are compatible with direction of building.

4.4. Color quality and radiated surface

Radiation intensity on different surfaces has direct relation with material and reverse relation with color brightness and air flow. Dark colors reflect only 15% and bright colors reflect 90% of energy. It is better to use dark colors in building according to climate of region in order to absorb heat in winters.

4.5. Aeration

Regarding that the climate we studied had humid winters and dry summers, aeration is important in summers because in hot summers aeration prevents air pollution in house and can be done by opening the windows. At this time because outside weather in cooler than inside we can create draft. In cold seasons at first we should prevent entering the cold weather and in summer we should use natural aeration and by choosing proper materials in housing we can control internal aeration.

4.6. Effects of shape and type of window

If windows have sunshade and air flows, the direction has no effect on internal temperature but if there is no sunshade then using light weight materials will be important (Moradi, 2005).

Suggestions of designing according to climate of Mashhad

- Use heavy materials
- Use compact plans
- Consider small openings
- Consider outside spaces for summer usage
- Minimum external surface
- Locate the building close to each other
- For individual buildings cubic form and square plan is important
- In order to reduce wind speed, plant evergreen trees on SE and NW side for distance of 13/5 time of tree height, 50% of wind speed will reduce.
- Use joint walls
- Don't build in hollow grounds
- Consider warm spaces in center of plan
- Don't use big windows specially on north side
- Minimum entrance and locate the mail entrance leeward
- Upper level than yard and yard should be lower that street

- Consider basement
- Consider green space and planting
- Consider central and complicated hallway
- Consider thick walls (Salamat, 2001).

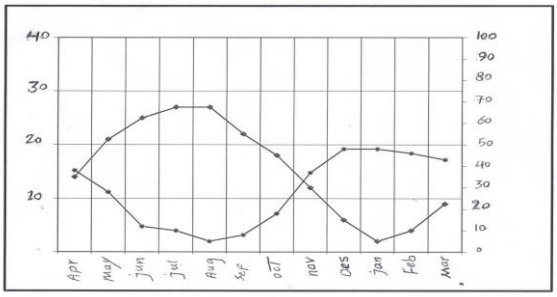

Figure 2: Ombrothermic chart of Mashhad in 12 years

4.7. Analysis of ombrothermic chart

In this chart we first we consider temperature toward seasons of the year and then we bond the dots and we did the same for humidity. Where the two lines cross each other, closed shape is created and in the chart above intensity of dryness in more. According to the chart arid period is from beginning of April until beginning of November and the rest of the seasons belong to humid period.

Chart 4: materials specification

Materials	Delay time	BTU-Ft/hr.ft²ºF	BTU/F³ºF
adobe	10	0.37	19.6
Normal brick (pef120) (FCF120)	10.4	.42	24
Facing brick (130)	6.1	075	26
concrete (PCF140)	7.5	1	29.4
gypsum	12.4	025	20.3
limestone	8.9	054	22.7
marble	6.6	1.5	34

Chart 5: building material reflection

Material type	Thermal diffusivity	Heat Reflection(%)	Sun Reflection(%)
Polished marble	0.90	-	50-40
limestone	0.95	5	43
Concrete	0.88	-	40
Pine wood	0.95	5	40
Light and dark brick	0.95	5	48-23
Asbestos	0.96	-	19

Chart 6: reflection coefficient of materials

Materials	Reflection (%)
Granite	10-25
concrete	10-50
Asphalt	8-15
Stucco grout	20-30
Stucco grout	40-50
White tile	75-87
Bright glass	6-8
Wavy glass	5-15
limestone	35-65
White marble	80
Fresh dry gypsum	80
Portland cement	20-45
brick	10-25
tile	80
Aluminum	55-60

4.8. Analysis of absorbance and reflection coefficient chart

We know that in hot regions reflection coefficient must be high and in cold regions dark colors absorb heat. In Mashhad climate regarding that in half of the year we are under thermal comfort indices it seems that using materials like marble can be appropriate and saves energy.

4.9. Analysis of thermal comfort indices (structural bioclimatic in Mashhad)

4.9.1. Olgy method

It is possible to understand that the all parameters involved in the concept of comfort act together in different proportion. Also and most important, the concept of comfort is evoked by using two axes one vertical showing the variable temperature and another horizontal for the humidity variable (see Fig 3 bellow). According to this chart we can find out the different climates and permanency of cold and hot weather so we find that what types of mechanical systems are needed.

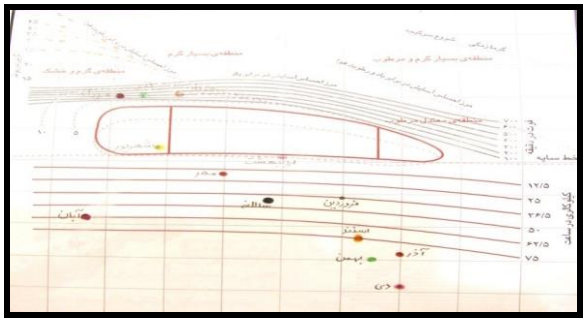

Figure 3: olgy bioclimatic chart

4.9.1.1. Analysis of olgy chart for Mashhad

June, July and august are above comfort area and comfort must be created by aeration and evaporation. In day time we can't feel comfortable unless aeration speed inside the house increases. In May although we are below comfort area but in day time and direct sunshine the temperature is inside the comfort area.

In October, April and March usually we don't feel comfortable unless we get direct sunshine or we use heating systems. Calculations show that for 2 degrees of temperature reduction we need 150 Watt sun radiation heat. In November, December and January the comfort must achieve by using the heating systems.

4.9.2. Givoni thermal comfort method

According to this chart we can find the climatic conditions and characteristics of a building to reach thermal comfort. Regarding chart6, with monthly average Max and Min temperature in 12

years and finding average monthly humidity the following figure has been created.

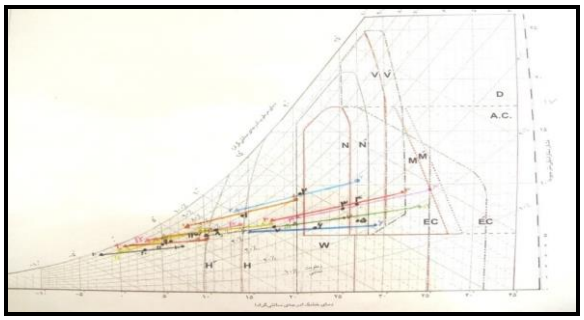

Figure 4: Givoni bioclimatic chart

4.9.2.1. Analysis of Givoni chart for Mashhad

In this chart, temperature and humidity in November is in H range and it is clear that by choosing proper material we can heat the building easily in April and October we are also in H range. In September and May we are in W range and there is no humidity. In June and July we are in N range that person feels comfortable but in December, January, February and march that we are out of H and Hó we must use heating systems in these month it is necessary that prevent sunshine and absorbance of sun radiation and use shades and trees outside the building and use bright colors for roof and walls and generally design compact plans for building and use insulation.

4.9.3. Baker's method

Baker's index or cooling index CP calculated as follow:

CP= (0.26+0.36V0.622)(36.5-t) Mcallcm2/sec

By using the information of a chart that mentioned in the beginning of this paper about recent 12 years we calculate CP and create following chart:

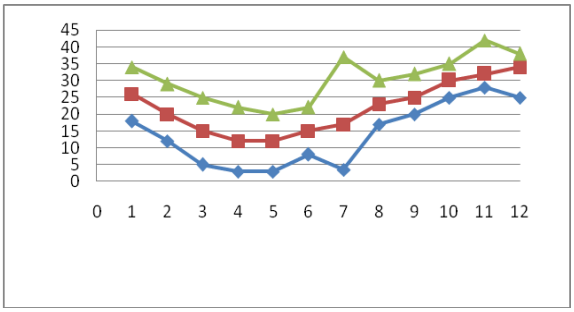

Figure 6: Baker's index chart for Mashhad

4.9.3.1. Analysis of Baker's index chart for Mashhad

According to Baker's method in April at daytime we are in comfort range and at night it is cold and unpleasant. In May, at daytime we are in comfort range but at night we are at C index. In June, at daytime it is hot and unpleasant and at night it is cold and unpleasant. In July, at daytime it is hot and unpleasant but at night it is cool. In august, at daytime it is hot and unpleasant but at night it is cool and pleasant. In September, at day time it is hot and unpleasant and at night it is cold. In October, at daytime weather is pleasant but at night it is very cold.

4.9.4. Terjung method

In this method temperature is based on Fahrenheit degree and humidity is shown in percentage. This chart shows how human feels according to weather (Terjung, 1968).

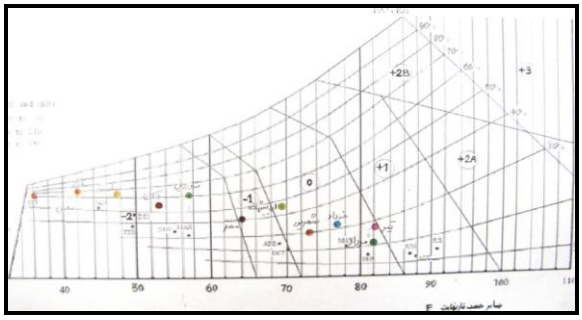

Figure7: Terjung chart for Mashhad

4.9.4.1. Analysis of Terjung chart for Mashhad

According to Terjung chart in April, thermal coefficient is -2 and it is cool, in May it is in range O and it is pleasant. In summer it is in range U that means weather is pleasant, in fall it is in group C which has cool weather in winter, thermal coefficient is -2 and weather is cold.

4.9.5. Mahani method

Mahani's chart shows the comfort area at day and night in a month regarding Min and Max temperature.

Chart 7: Mahani's index chart in Mashhad 36.16º North latitude and 59.38º East longitude Elevation: 999 meters

Des	Nov	Oct	Sep	Aug	Jul	Jun	may	Apr	Mar	Feb	Jan	Temp (C)		
10.63	17.53	25.68	29.16	33.86	35.21	32.70	27.31	20.35	13.29	10.16	7.67	Average monthly max temp		
0.32	5.12	10.17	13.98	19.68	20.58	17.85	13.83	8.25	3.34	-0.33	-2.38	Average monthly min temp		A
5.55	11.3	17.90	22.76	27.30	27.72	25.26	20.63	13.37	8.8	3.89	2.62	Monthly fluctuation of temp		
Des	Nov	Oct	Sep	Aug	Jul	Jun	may	Apr	Mar	Feb	Jan			
91	81	59.5	33.6	37.1	39	35.5	67.3	80	88.5	91.7	90	Average monthly max		
56.9	43.9	28.8	20.2	19.5	22	23.5	38.3	48.17	52	58.5	58	Average monthly min	Relative humidity	
69.58	57.37	39/53	29.7	25.3	35.21	31.12	48.8	59.45	63.8	67.6	69.66	average		
3	3	2	1	1	2	2	2	3	3	3	3	Relative humidity group		B
23.39	20.36	1.51	2.68	0.72	2.25	3.13	28.2	31.24	33.76	24.31	29.49	Precipitation (mm)		
↘	↘	↘	↘	↘	→	→	→	→	↓	↓	↘	Dominant wind	wind	
↓	↓	↓	↓	↓	↘	↑	↑	↘	↘	↘	↓	Wind runner mold		
Thermal indices														
												H1 necessity of aeration		
												H2 proper aeration		
												H2 necessity of fighting against rain		C
		*	*	*	*	*	*					A1 necessity keeping heat inside building		
				*	*	*						A2 sleeping at night out door		
*	*							*	*	*	*	A3 cold months problem		

Min temp: -0.44; Max temp: 35.2; Annual fluctuation: 13; Average annual temp: 13.48

Chart 8: Mahani's suggestion chart

suggestions	Thermal indices					
	A1	A2	A3	H1	H2	H3
expanded 40-80% the area north and south walls			1			
Medium 25-40% wall area			2			
Small 15-25% wall area			3			
Very small 10-20% wall area			4			
Medium 25-40% wall area			5			
on north and east walls, exposure to wind			6			
Like above, inside the inner walls			7			
Protect against direct radiation			8			
Protect against rain			9			
Light weight. Low thermal capacity			10			
Heavy, more than 8 hours delay			11			
Light weight, reflex			12			
Light weight, good insulation			13			
Heavy, more than 8 hours delay			14			
Space for outdoor sleeping			15			
Enough drainage for rain water			16			

4.9.5.1. Analysis of Mahani's bioclimatic indices

1- The main side of buildings face to NW and SE and long streets parallel with SE axis
2- According to fluctuation of temperature it is necessary to save heat in 11 months
3- Doors and windows must be 10 to 20 % of walls and located on north and south walls
4- Walls must be thick and conduct heat less than 8 hours
5- Roofs must be heavy with material of more than 8 hours delay

The need to heat inside the building is 6 times more than the need to cool.

CONCLUSION

In summer by adding humidity we can reach to comfort condition.

- Considering wind directions important in cold months
- In summer days weather is hot and at night it is pleasant
- Buildings form should be compact and cubic
- Flat roofs
- Use external dark colors and lower height inside
- Materials with high thermal capacity is appropriate and resistant to humidity
- Landscaping and creating green spaces is good in this region

We expect by considering the issues mentioned in this paper, thermal comfort of inhabitants achieved and reduce energy wasting.

REFERENCES

Alijani M. Thermal comfort in Tabriz. Nivar journal 1994;12(2):45-54.

Alizadeh A. Studying frost in fall and spring in Mashhad, Master thesis, 2002.

Babaean I. synoptic analysis of Mashhad's climate. Nivar journal 2002;20(8):412-416.

Bani V. providing model to forecast Mashhad's monthly temperature, Master thesis, 2004.

Emmanuel R. Thermal comfort implications of urbanization in a warm humid city: The Colombo metropolitan region (CMR); Sri Lanka. Building and Environment 2005; 40(2): 55-63.

Farajzade GH, Lashkari H. evaluating adaptation of Sanandaj city architecture with climatic condition according to Mahani method, Master thesis, 2002.

Jahansson E. Influences of urban geometry on outdoor thermal comfort in a hot dry climate; A Study in Fez, Morocco. Building and Environment 2006;41(2):252-258.

Johnson V. climate and architecture with emphasis on Middle-East architecture. geography research quarterly 2002; 46(8): 520-522.

Kaviani M. essay on evaluating bioclimatic providing in Iran, Master thesis, 2004.

Mansouri T. synoptic analysis of climatic statistics in Khorasan, Master thesis, 1996.

Moradi M. environmental situation. Adineh book publication, 2005.

Razjooyan M. comfort by compatible architecture with climate, Master thesis, 2009.

Salamat A. Khorasan Razavi climatic classification, Master thesis, 2001.

Samadi S. evaluation of synoptic systems in Khorasan Razavi, Master thesis, 2006.

Terjung WH. world patterns of the monthly comfort index. International journal of biometeorology 1968;12:1025-35.

Tousi A. drought forecast in Khorasan. Geography research quarterly 2003; 70(4): 354-362.