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Research Article

INVESTIGATING THE EFFECT OF CLIMATIC ELEMENTS ON URBAN ARCHITECTURE: A CASE STUDYIN GARMAB

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ABSTRACT
Climate is an important and effective factor in biological comfort in human environments. In this regard, housing as a shelter protects humans against heat and cold and environmental disasters, and is directly related with climate. This research tries to study the climatic condition of Garmab to provide guidelines for creating comfort through appropriate building designs which are compatible with climate of the region. For this purpose, the required meteorological statistics for a statistical period (from their establishment until 2011) was obtained from the meteorological data sites.Then this information was analyzed applying the library studies method. First, the Karimi, Domarten and Amberze classification methods were used to specify the climate type. Then, Mahoney method was applied to evaluate the thermal comfort indices of the city. At the end, proper strategies were offered for greater consistency between architecture and the climate.

Keywords*: Architecture, Climatic Design, Mahoney Indices, Degree of Comfort, Garmab City*

INTRODUCTION
Climate is one of the most important environmental factors and highly affects humans' behavior and their overall state. One of the major effects of climate on human life is housing construction in accordance with the climate conditions and providing thermal comfort in them (Kalantari*et al.*, 2014). Housing is regarded as one of the primary needs of man and plays an important economic role in addition to its functions as urban housing.Among these factors, the weather is an important factor which affects the shape of the housing (Khvran, 2006). Climatic design is a method for reducing overall energy cost of a building. The building design is the primary defenseagainst climatic factors. In all climates, buildings that are built on the principles of climatic design, reduce the need for mechanical heating and cooling to a minimum; Instead, they use natural energy surrounding the buildings. It leads to saving energy and helps the optimal use of environmental conditions to improvecomfort for living inside buildings. In sum, it can be stated: Changes in climatic conditions have a significant impact on living conditions and human comfort. Physiologically, the thermal comfort condition is a range of temperature and humidity in which the body's heat regulating mechanism activity is at a minimum (Bahrami, 2007).
Therefore, the importance of the impact of climate on architecture signifies extensive researches and studies in this area. Especially in Iran which variety of climatic conditions is quite evident, extensive researches in this area is inevitable. Taking into account the formation and composition of vernacular architecture in Iran, we realize that the different characteristics of each of these climates have had a great influence on the formation of cities and architectural composition in these regions. Therefore, accurate determination of climatic zones in the country and achieving the climatic characteristics of various zones is very important in providing appropriate designs which are in consistence with the climate of each region (Ghalehbin*et al.*, 2013). Nowadays, the knowledge of climatology has gained a special place in earth sciences, especially in geographical science. Considering the role of climate in urban construction, limited researches have been done in recent years in Iran (Safaeiand Taheri, 2010).But in Garmab, there has been not a comprehensive research in this regard. Therefore, this study investigates how climate is applied in architecture of Garmab city to provide favorable comfort and reduce energy consumption and make a better use of climate conditions and parameters. In so doing, temperature, precipitation, humidity and some other parameters were obtained from the province Meteorological Organization for the period

of time since the establishment in 2008 and Bio-climatic conditions in buildings were studied using Mahoney's thermal comfort limits.

Methodology

The geographical scope of investigation is Garmab city. First, some climate elements (temperature, humidity and precipitation) of the synoptic station since its establishment in 2011 are analyzed and the climate of the city is described and classified based on Karimi and Domarten method, then the method of Mahoney is used to determine the characteristics that a building should possess regarding the surrounding climatic conditions. After evaluating the climatic function ofbuilding elements and determining the thermal requirements ofbuildings in the climatic conditions of Garmab city, ways to meet these requirements is proposed.

MATERIALS AND METHODS

The indoor air temperature, regardless of the internal heating elements or heating systems, is subject to climatic conditions. The effect of climatic conditions on the thermal status of indoor depends on constructional properties of buildings' external walls. Mahoney criteria are used to evaluate human comfort conditions within the building and the effect of climatic conditions on the physical characteristics of the building.

In this study, bio-climatic conditions of a building in Garmabareevaluated using Mahoney method. In 1970, Carl Mahoney and his colleagues took the role of buildings into consideration. In this method, first with respect to temperature and relative humidity in each month of the year, daily fluctuations, annual fluctuations, the average air temperature and weather conditions are examined in relation to human comfort (Safaeiand Taheri, 2010).

Investigating the Climate Characteristics of Garmab

The goal of climate studies in urban design is identifying the environmental characteristics that are influenced by climatic conditions that is prevailing the environment. Climatic elements affects determining the direction, shaping the fabric, neighboring parts, street network formation, positioning a variety of activities, its role in air pollution or purification, urban landscapes, livelihood means and etc..Types of climate and its annual or seasonal changes, in order for people to build their living space, forced them to established residential areas with regard to climate in which they are living.

Doors and windows dimensions, wall thickness, shape and form of the building, roof type, construction materials, height of buildings and etc. are in consistent relation with environmental conditions particularly climatic elements.

To investigate the characteristics of a region or city, its climatic parameters need to be studied. Therefore, to investigate the climate of Garmab city,the data obtained from Garmab's Synoptic station was used, which is located in 48°11'E longitude and 35°50'N latitude geographical coordinates and altitude of 1600 meters above sea level.

In this study, parameters such as temperature, precipitation, humidity and other parameters are obtained from the province Meteorological Organization for the period of time since its establishment in 2008 and studied.

The temperature of the Region

Air temperature and its changes over days, months and years areamong the important climatic parameters which may influence the formation and properties of critical ecosystems. Air temperature is afactor that affects design of buildings, construction materials, infrastructure-level position relative to the ground level, segmentation of land towards thermal equilibrium, the ratio of building floor excretion or absorption of heat,road construction materials regarding ambient temperature and etc.. Therefore, the temperature statistics obtained from Khodabandeh synoptic station is used to study the temperature of Garmab, (Figure 1)

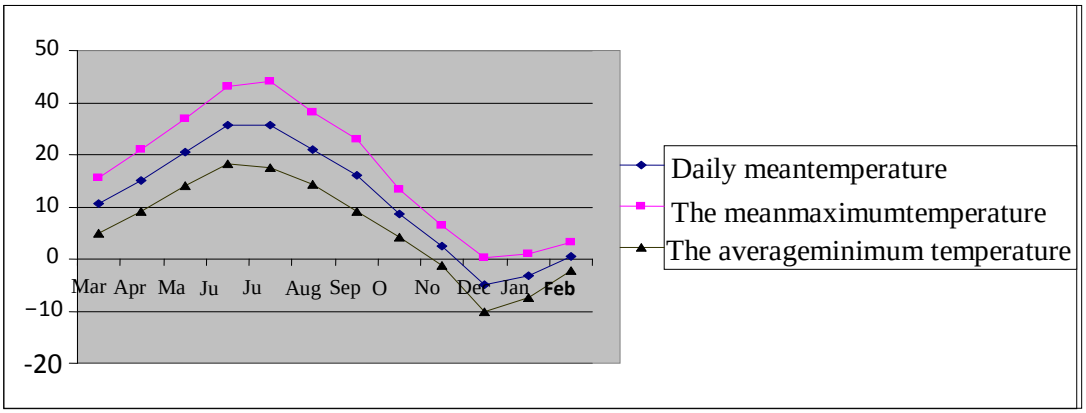

Figure 1:Garmab's temperature according to Garmab synoptic station (Source: Meteorological Bureau of Zanjan province)

The monthly mean temperature is the result of averaging the daily mean temperatures during each month which shows the overall monthly temperature status for each location. Changes in monthly mean temperature of Garmab stations show that the mean temperature in December which is the coldest month of the year, reaches its minimum and the mean temperature for the month in each year approximately is -4.9 degrees centigrade.. The monthly mean temperature slightly increases during the months after winter, in February -3.1° C and March 0.4° C.

The mean temperature substantially increases by the beginning of spring in March to 10° C. Increase in the mean temperature continues during May and June, and reaches itshighest level during July and August,25.6 and 25.8 ° C. In September and October, the monthly mean temperature decreases to 21.1 and 16 ° C,respectively. From November onwards, the monthly temperature decreases rapidly so that it reaches to 8.7 in November and 2.5° C in December. The annual mean temperature in Garmab is 11.5° C. As the table of Grmab synoptic stations temperature indicates, the thermal peak of the city is during summer and August and then the temperature decreases during the next months. The cold usually starts in late November and early December.

The Precipitation of the Region

This parameter indicates the amount of atmospheric precipitations, both solid and liquid the yearly, monthly and daily. Atmospheric precipitations (rain, snow, hail) in urban studies, affects road width and slope, buildings' roof type, disposal of surface water, construction materials, etc. The annual mean precipitation at this station is about 227.1 mm.Precipitation in winter usually is in the form of snow.

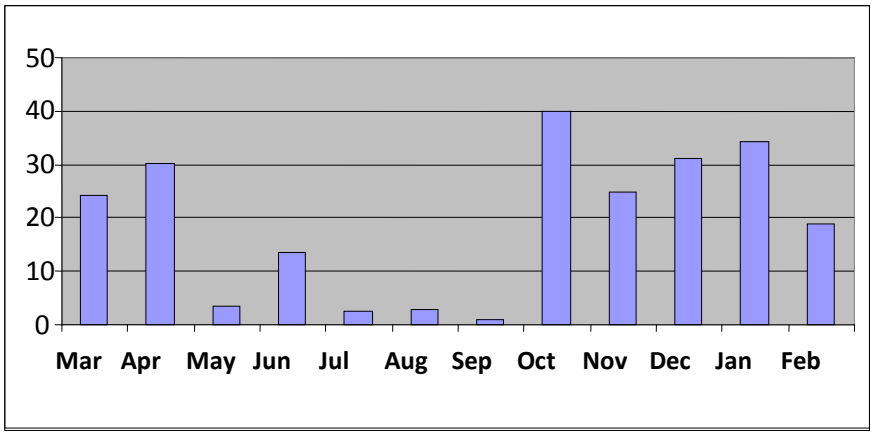

Figure 2:Garmab's average precipitation according to Garmab synoptic station (Source: Meteorological Bureau of Zanjan province)

In terms of seasonal distribution of precipitation throughout the year, it is 25.5% in spring, 8% in summer, 29% in autumn and 37.5% in winter. The highest amount of precipitation is in the November with 39.9 mm the and lowest precipitation is in October with 1 mm (Figure 2).

The Humidity of the Region

Studying the increase and decrease ofthe relative humidity parameter reveals that with the beginning of autumn, which coincides with the beginning of precipitation systems activities in the country, the amount of relative humidity increases, and activity level of precipitation systems migrated to Zanjan province, Khodadabandeh City,.... humidity amounts, will also change and increase. During cold season, air mass and precipitation systems activities which coincide with increase in relative humidity, the temperature of the region decreases and in most cases, the highest amounts of relative humidity occurs during the coldest moths of the year. During November and December, the activity of Siberian and Polar high pressure centers increases, with the spread of their cold waves to the lower geographical latitudes and reaching the cold waves into Iranian plateau and also intensification of low pressure Mediterranean centers, Cold seasons precipitations occur which consequently cause a reduction in air temperature andincrease in humidity over Iran, Zanjan province, Khadabandeh county and Garmab city. The table below shows the monthly mean for relative humidity, mean for maximum and for minimum relative humidity arein percentage.

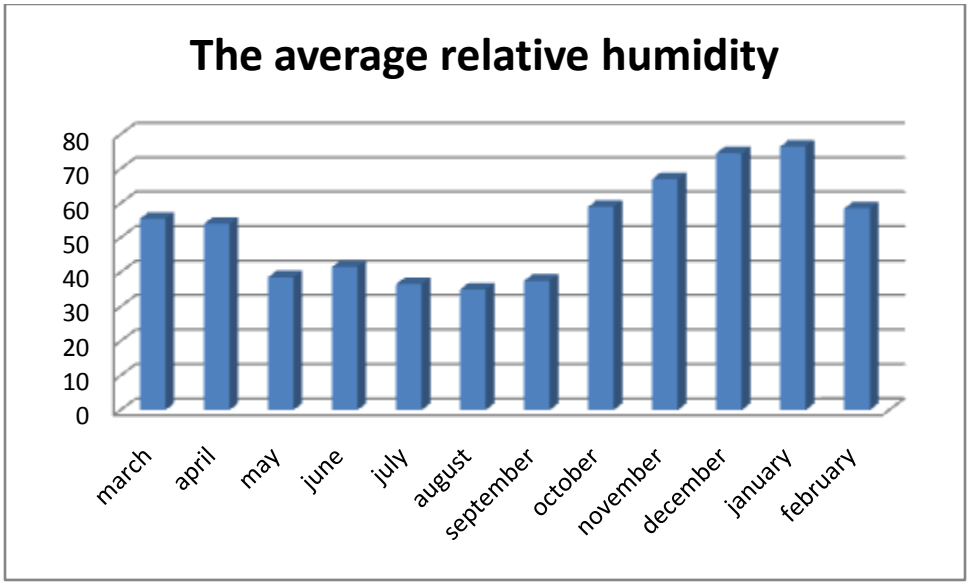

Figure 3:Relative Humidity (Source: Meteorological Bureau of Zanjan province)

According to Figure (3), the average annual relative humidity in the area is about 53% and the highest amount of humidity is in winter. The relative humidity in autumn and winter are more than 50% and during spring it reaches to about 50% and during summer reaches to about 30%. Generally, the highest relative humidity amounts are in cold and rainy seasons and the lowest amounts are in warm seasons. The city's highest monthly humidity is 76.5% in February which gradually decreases towards spring. The monthly mean relative humidity reduces to 58% in March.With the onset of spring and the transition into warm season, the amount of relative humidity decreases and reaches to 55.5% in April and 54% in May. The monthly mean relative humidity during the months of June, July and August is about 39%. The lowest relative humidity in this region occurs in September which is 35%. The relative humidity increase begins with the onset of autumn, so that its amount in October is 37.5%, in November is 59% and in December is 67%.so the driest month in Garmab is August and the most humid month is February.

Sunshine Hours for the Region

The effects of sunlight includes design in the shade or with sunlight according to different conditions, adjusting the environmental conditions to the light, distance between buildings toward sun angles, directions of the streets, etc.Sunshine duration and cloudiness are inversely related, with cloudiness increase the sunshine decreases. Thus, during the cold months, in which the cloudiness increases, the amount of sunshine decreases and during the warm months it increases.

Based on the data in Table (1) in Garmab synoptic station, the total sunshine hours in this region is 2905.2 which is equivalent to 121 days. Also,the highest monthly sunshine is in June about 351.2h equivalent to 14.6 days and the lowest monthly sunshine is in January about 143.8h equivalent to 6 days.

Table 1: Total monthly sunshine hours in Garmab synoptic station

Month	March	April	May	June	July	August	September	October	November	December	January	February	**Annual**
Monthlysunshine	184.3	239.8	351.9	346.2	317.5	302.2	267	185.5	197.4	143.8	160.7	208.9	2905.2

Source: Meteorology website

Climatic Classification of the Region

Three methods of Karimi,Domarten and Ombrothermic diagram are used for climatic classification of the station

KarimiMethod: In this method, Karimi uses 3 indices of heat, cold and humidity to determine the climate. This method is used to calculate the humidity index for the Khadabandeh station. The humidity index for the station was 2.96, and according to table 2, the climate of this station is semi-humid.

Table 2: Classification of Karimi humidity index

MoistureindexKarimi(I)	**Climate**
I<0.5	Veryhumid
< I < 10.5	humid
1 < I < 3	Semi humid
3 < I <6	Semi-arid
6 < I < 10	Dry
10 < I	Very dry

*DomartenMethod:*Domarten uses 2 indices of temperature and precipitation to determine the climate of a region. According to statistics available, the Domarten index for Garmab station is calculated as 10.56 which is the indicator of Semi-arid climate.

*OmbrothermicDiagram:*Figure 4 shows the monthly mean temperature and monthly precipitation for each station. This diagram shows the weather stations in dry periods. The Ombrothermic diagram is drawn based on the data obtained from the Khodabandeh synoptic station.

As can be seen in the diagram, there is a dry period in Garmabstation which begins in June and continues to October.

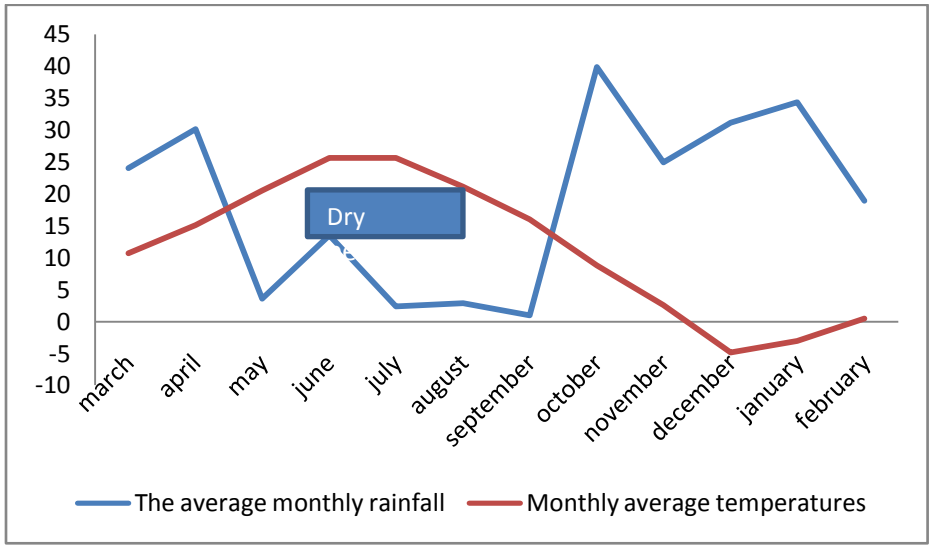

Figure 4:Ombrothermic diagram of Grmab station:

The Effect ofClimate on City's Architecture

In this part, the temperature of the day and night for each month in relation to human comfort will be examined.Mahoney's proposed method is used for this purpose. In this method, human comfort conditions are studied with respect to both temperature and humidity. In this study,first the mean of maximum and minimum temperatures and daily air temperature differences for each month of the year is tabulated and with respect to these factors. The annual mean temperature is calculated. Similarly, with respect to these factors, the average minimum temperature and relative humidity of each month, the humidity group ofeach month is determined.

"Hot" when the average temperature is above comfort level, "Appropriate" when the average temperature is in comfort level zone, "Cold" when the average temperature is below comfortlevel.

The following steps should be followed: the temperature index (day and night) of the monthly mean temperature fluctuations humidity group form table (1) is compared to index definitions. If desired condition matches the index definitions, a (×) sign will be laid in the index table in the month column and the related index.

Table 3: Geographic location of Garmab

Place Name	**Garmab**
Longitude	**1148**
Latitude	**5035**
Altitude	**1600**

Table 4: The monthly mean of maximum and minimum temperatures of Garmab, in degrees Celsius during the statistical period

Temperature C	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
The maximummonthlyaverage	0.3	1.1	3.1	15.6	21.1	27	33	34.1	28.1	23	13.4	6.3
Averagemonthly minimum	-10	-7.4	-2.3	5	9.1	14	18.2	17.5	14.2	9.1	4.1	-1.2
Averagemonthlytrading	10.5	8.5	5.4	10.6	12	13	14.8	16.6	13.9	13.9	9.3	7.5

The annual average=11.5,

Maximum= 16.6

Averageannualfluctuation= 11.3

The lowest=5.4

Table 5: Humidity group

Group'shumidity1if therelative humidityisless than 30 percent.
Groups2, if the relative humiditybetween30%humidityto 50percent.
If therelative humiditybetween50%humidityGroups3to 70percent
HumidityGroups4, while relative humidityisgreater than 70percent.

Table 6:The percentage of highest and lowest monthly relative humidity of Garmab

Relative humiditypercent	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
The meanmonthlymaximum(AM)	76	79	75	68	69	60	51	51	43	60	63	78
The meanmonthly minimum(pm)	69	70	58	45	41	33	26	26	20	38	45	52
Average	72	69	59	49	43	32	34	28	29	41	57	9
Groupshumidity	4	3	3	2	2	2	2	1	1	2	3	3

Table 7:The prevailing winds of Garmab

January	February	March	April	May	June	July	August	September	October	November	December	**Prevailing winds**
South East	South East	West	Souh west	South west	North west	South East	South East	South East	South	South	South	

Tables 8:AboutComfort

AboutComfort			
Less than15	**15-20**	**The annual averagetemperatureis over 20**	**Grouphumidity**
DayNight	**DayNight**	**DayNight**	
21-3012-21	23-3217-25	26-3417-25	1
20-2712-20	22-3017-24	25-3117-24	2
19-2612-19	21-2817-23	23-2917-23	3
18-2412-18	20-2517-21	22-2717-25	4

Table 9: Day and night comfort limits of Garmab

TableDetection	April	May	June	July	August	September	October	November	December	January	February	March
The maximum monthlyaverage	15.6	21.1	27	33	34.1	28.1	23	13.4	6.3	0.3	1.1	3.1
The highlevelofcomfortinthedays	26	26	27	27	27	27	26	26	26	24	26	26
The lower limitonwelfare	19	19	20	20	20	20	19	19	19	18	19	19
Averagemonthly minimum	5	9.1	14	18.2	17.5	14.2	9.1	4.1	-1.2	-10.2	-7.4	-2.3
The highlevelofcomfortat night	19	19	20	20	20	20	19	19	19	18	19	19
Toolow forcomfort at night	12	12	12	12	12	12	12	12	12	12	12	12
In theheatofthe day	Cold	Appropriate	Appropriate	Hot	Hot	Hot	Appropriate	Cold	Cold	Cold	Cold	Cold
In theheatofthe night	Cold	Cold	Appropriate	Appropriate	Appropriate	Appropriate	Cold	Cold	Cold	Cold	Cold	Cold

Tables 10: The meanings of indices in Mahoney table

		Temperatureconditions			
IndicatorsThe concept	**Day**	**Night**	**Rain**	**Grouphumidity**	**Monthlyfluctuations**
Air flowis essential (H1)	Hot			4	
	Hot			2,3	<10
Optimalairflow (H2)	Appropriate			4	
Protected fromrain (H3)			>200mm		
Heat capacityis essential (A1)				1, 2,3	>10
Sleepis essentialforspace (A2)	Hot	Hot		1,2	>10
Protectionagainst the cold (A3)	Cold	Appropriate			

Table 11: Indices

TableDetection	March	April	May	June	July	August	September	October	November	December	January	February	
Moisture H1													
H2													
H3													
Drought A1	×	×	×	×	×	×	×						**7**
A2													
A3	×							×	×	×	×	×	**6**

Table 12: Mahoney architectural proposals for Garmab city

TotalIndexofTablesgroup					
H1	**H2**	**H3**	**A1**	**A2**	**A3**
0	**0**	**0**	**7**	**0**	**6**

Table 13:Placement of buildings

North-southdirection(longer axis ofthe building intheEast-West)	**1**	×	**5-12**	**0-10**			
Compact designaround theyard	**2**		**0-4**	**11&12**			

Table 14:Spatial adjustment (spacing)

Widespatialplanfor the use ofair	**3**							**11&12**
Same asabove,butprotectedfromcoldwinds	**4**							**2&10**
Compact spaceplan	**5**	×						**0&1**

Table 15:Airflow

Predictedsteadystreamof airtoallrooms,doublerooms, which are connected totheexternalenvironment.	**6**						**0-5**	**3-12** **1 and 2**
Predictedthat one sideroomswithaircontact, they foreseethe temporalflowof air	**7**	×			**6-12**		**2-12**	**0**
Air flowis not necessary	**8**						**0 and 1**	

Table 16:Openings

Grandopeningsof 40-80percent	**9**		**0**	**0 and 1**
10-20% of verysmallopenings	**10**	**0 and 1**		**11 and 12**
40-20% of medianopenings	**11**	×		**Anyothercondition**

Table 17:Walls

Wall light low latency	**12**		**0-2**
Inner and outer walls of heavy	**13**	×	**3-12**

Table 18: Roofs

Heavy roofs with thermal insulation	**14**		**0-5**
Latency heavy roofs over 8 hours	**15**	×	**6-12**

Table 19: Protection against rain

Predictprotection againstheavy rains	**16**	**3-12**

CONCLUSION

The importance and necessity of taking climatic conditions into account in the design and construction of all buildings, particularly in Garmab city is proven. This study is done aiming at evaluating the climatic conditions and climatic comfort in Garmab. Therefore, Mahoney comfort determination method is used. According to the results of the study, first the mean of the maximum and minimum temperatures, and daily air temperature differences for each month of the year is tabulated and with respect to these factors. The annual mean temperature is calculated. Similarly, the humidity group is determined with respect to these factors,the lowest and the highest temperature and the mean of relative humidity. The results show that it is cold during days in 5 months of the year and during nights in 8 months of the year. it is cold in 8 month of the year and appropriate in 4 months of the year. So, there is no need for air cooling during the nights of whole year, but cooling is needed during days for 3 months of the year(May to July). But air cooling is required for four months of the year during days and 4 months of the year during nights.

Given the cold climate of Garmab in winters and its hot and dry climate in summers, it is recommended that:

- Building plans shouldbe designed compact and dense.
- The direction of buildings and rooms should be toward the east-west direction.
- Roofs should be built flat, using heavy materials (concrete and brick) with appropriate delay.
- The permanent airflow for all roomsshould be predicted,especially the rooms on both sides which open to outer space.
- Double-glazed windows should be used and insulatedin winters; also, all building exits, including doors and windows should be insulated.
- The buildings should be designed to be protected against heavy rainfall, and use them as much as possible.

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