

Climatic Building Envelope Employed in Vernacular Residential Architecture in Golestan-Iran

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ABSTRACT: Climate is one of the many factors such as socio-cultural values, economics, materials, administrative factors and technology that influence architectural forms. The climatic solutions effecting on architecture, differ in various regions, cultures, time and technology. The climate of the province of Golestan plays an active role in the formation and diversity of vernacular dwellings. This region is in contact with numerous environmental factors. It is limited by Alborz Mountain in the south, by Turkmenistan desert in the north-east, and by Caspian Sea in the north-west bringing about high humidity in this province. With this background, the paper's question raised: "How do the climatic design principles of vernacular architecture respond to microclimates in this region?" In this paper, the focus is on building's envelopes and shells in three local climatic scopes of the region. The paper is based on a combination of research methodologies: field research (integrating case studies) and archival research. The climatic data are being analyzed by Mahoney tables providing preliminary design recommendations. They are grouped under eight headings: layout, spacing, ventilation, openings (size, position and protection), the relation between building and ground, veranda, wall and roof. This essay argues about the knowledge and skill of vernacular and traditional bioclimatic construction suggesting conceptual strategies for improve current dwelling aiming to a sustainable future.

Keywords: Vernacular architecture, Building envelope, Environment, Microclimate, Golestan, Iran.

INTRODUCTION

The building envelope may be defined as the totality of (building) elements involving components which separate the indoor of the building from the outdoor. They are made according to various criteria such as environmental, technological, socio-cultural, functional or aesthetic factors. Among all environmental factors, by only controlling physical-environmental factors such as heat and light, the outcome will be more desirable in the case of thermal and visual parameters. In vernacular and traditional buildings, the main function of the building envelope -respecting to physical environmental factors- is to provide thermal comfort by controlling the influence of climatic elements, as well as visual comfort by controlling the natural light (Oral et al., 2004). Understanding the traditional architecture features in the terms of heat, humidity, wind and sunlight, provides useful experiences for present design resulting gradual evolution in a long period of time. In many countries, there are special guidelines and standards

for environmental design and sustainability emphasizing on region characteristics. Now a days, environmental attributes and local patterns are the indicators of sustainability in more communities (Tafahomi & Lamit, 2011). The familiar elements of regional architectural styles (verandah, balconies, shutters, etc) are being created to control the condition of the building for a certain degree of comfort. Understanding the traditional vernacular architecture will have lessons for designers in the case of Climatic design. These lessons contribute to energy saving which is the focus of many urban scientists all around the world (Indraganti, 2010).

The aim of this paper is to evaluate the role of building envelope in vernacular and traditional architecture in three separate climatic zones in Golestan province, according to the type of construction, climatic performance of building envelope, and climatic elements and parts used in the body of buildings. Results show that the identified forms have general common features. Some of these common features, construction details and materials and method of controlling the climatic factors, etc

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have been evolved according to their local bioclimatic zone. Therefore different methods and climatic elements are used in building envelope, to provide the comfortable living conditions. Such a building environment acts as a living organism that is inherently sustainable responding to various bioclimatic changes with a minimum waste of resources (Maria, 2009). The aim of this paper is to evaluate the role of building envelope in vernacular and traditional architecture in three separate climatic zones in Golestan province, by researching about the type of construction, climatic performance of building envelope, and climatic elements used in the body of buildings. Results show that the identified forms, have general common features. Some of these features, construction details and materials, methods of controlling the climatic factors, etc have been evolved according to their local bioclimatic zones. Therefore different methods and climatic elements are used in building envelope, to provide a comfortable living condition. Such buildings act as a living organism that is inherently sustainable responding to various bioclimatic changes with a minimum waste of energy (Maria, 2009).

The analysis consists of two major parts. The first part studies the environment, specified by climatic zones identifying types of vernacular residential architecture in the region. The second part analyzes the building envelope, method of construction and their relation with environment at each identified types of the architecture in the region by studying the elements and components used in the building envelope and shell of vernacular houses.

MATERIALS AND METHODS

In this paper, three different types of architecture in Golestan province have been identified consisting of urban residential units in plain and flatlands, residential units in hillside areas as well as villagous residential units in steep of mountains. The focus is on the building envelope and relation between body of the building and microclimates of vernacular architecture in the region. Data was gathered through observation, measurement, photography, filming and interviews during a year ended by 8/2011. The data of the wall temperatures shown in the Table 4, Fig. 2 and Fig. 3 have been measured by a sensor which has been made in the lab of Qazvin Islamic Azad University (Fig. 1). The collected data was compared and assessed. The climatic data were analyzed by Mahoney tables providing preliminary design recommendations. As mentioned, they are grouped under eight headings: layout, spacing, ventilation, openings, position of openings, protection of openings, walls and roofs. Vernacular architecture has been misremembered in most places. In plain zones of the city of Gomishan, the vernacular architecture has mainly remained, but in hillside zone of the city of Gorgan, and the steep of mountains of two villages in Olestan and Cheli Sofla, only some of the oldest houses with more than 100 year old were valuable to be compared and assessed. Among all, twelve cases have been completely explained in this paper. A collection of evidences in the form

of photographs, have been used for better comparison and assessment. The illustrations include building envelopes, details of construction and elements used in the body of buildings.

Environmental-Cultural Features of Golestan

- History and Status of Location

Golestan is located in the south-east of the Caspian Sea between northern ranges of east Alborz mountains and Atrak river (Badiei, 2000). Golestan and the plain of Gorgan have a history of 10000 year old in early civilization. Excavations in Shah tappe, Yaram tappe, Torang tappe and Dashte Ghale show that this region has been one of the important civilized places earlier than the areas in the north and north east of Iran (Kiani, 1987). Based on studies applied by archeological center in JorJan, many castles and cities of pre-islamic and Islamic eras have been found in this region (Kiani, 1992).

Since Gorgan has been invaded by nations of the north east, it has become a place for settlement of different tribes. Nowadays this region is a center for different tribe relations such as Arian race, Mongolians and Toranies (Moeini, 1966).

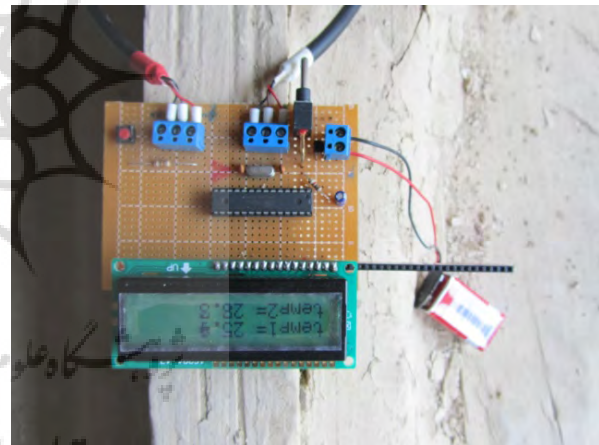


Fig. 1: The instruments used for field measurements of the wall temperatures

Study of Climatic Conditions of Golestan The General Climatic Features of Golestan

The most critical factors effecting on the condition of a specified region are Latitude, and climate which cause thermal variation (Coach, 1998). Among four climatic divisions of Iran (that has been suggested by Dr. Hasan Ganji), Golestan fits into the moderate and humid areas of Caspian Sea shores. The more we go towards the east in southern shores of Caspian Sea, the less humidity and rainfall there is (Fig. 2a). In this area the average temperature is between 25 to 30°C in summer and 0 to 5°C in winter (Kasmai, 2006).

Different Climatic Zones based on Different Vegetation

The secondary factors, which contribute to this condition, are: Height above sea level which decreases average temperatures, and increases the temperature variation, but usually lowers the humidity.

The topography, with countless microclimatic variations because of its relationship with sunshine and prevailing winds. Vegetation and development factor: while the vegetation brings about greater stability in temperature and more humidity, development of human settlements causes higher temperature variation and less humidity (Coach, 1998).

As mentioned before, this province is adjacent to Alborz Mountains from the south. So the southern areas have higher level. When we go towards the northern areas, its height becomes lower near to Caspian Sea and the desert of Turkmenistan. Therefore, the vernacular architecture of the province in this study were reviewed in three following areas (Fig. 2b).

Plain of Gorgan: It has cold winters and warm and very humid summers. Average minimum temperature is 9/67°C in December- January and average maximum temperature is 28/95°C in July-August. Prevailing wind is from west to east (Organization of cultural heritage, 2008).

Hillside areas: This region has moderate and humid climate. This area is located in the south and the east of the province

and at the foot of the mountains (Moeini, 1966). According to the statistics report of 12 consecutive years from Sinoptic weather station in Hashem Abad, the average of maximum temperature in Gorgan is 33/1°C and average of its minimum is 4/1°C (Consulting Engineers of Architectural Design, 1997).

Mountainous area: This zone is located at the extension of east Alborz mountains from the west to the east and gradually tends towards the north east and where the height is low (Shabani et al., 2006). This areas with less than 1000 meter altitude, have moderate and humid weather surrounded by jungles. In areas with 1000 meter high and more, the density of jungle and humidity of weather gradually reduce (Moeini, 1966). In winter, due to blowing of Siberian winds in mountains, density of clouds, amount of snow and rain in this climate increases, and the weather becomes very cold, while it is moderate in summer (Ibid).

Golestan Vernacular Architecture in Studied Zones

This part of the research has been conducted to study the general features of vernacular architecture in Golestan including plan types, land uses, the relations between components of the plan, and the relation between open, semi open and closed spaces.

The Characteristics of Vernacular Architecture in the Plain Zone of Gomishan

The houses in plain zone have been designed and constructed

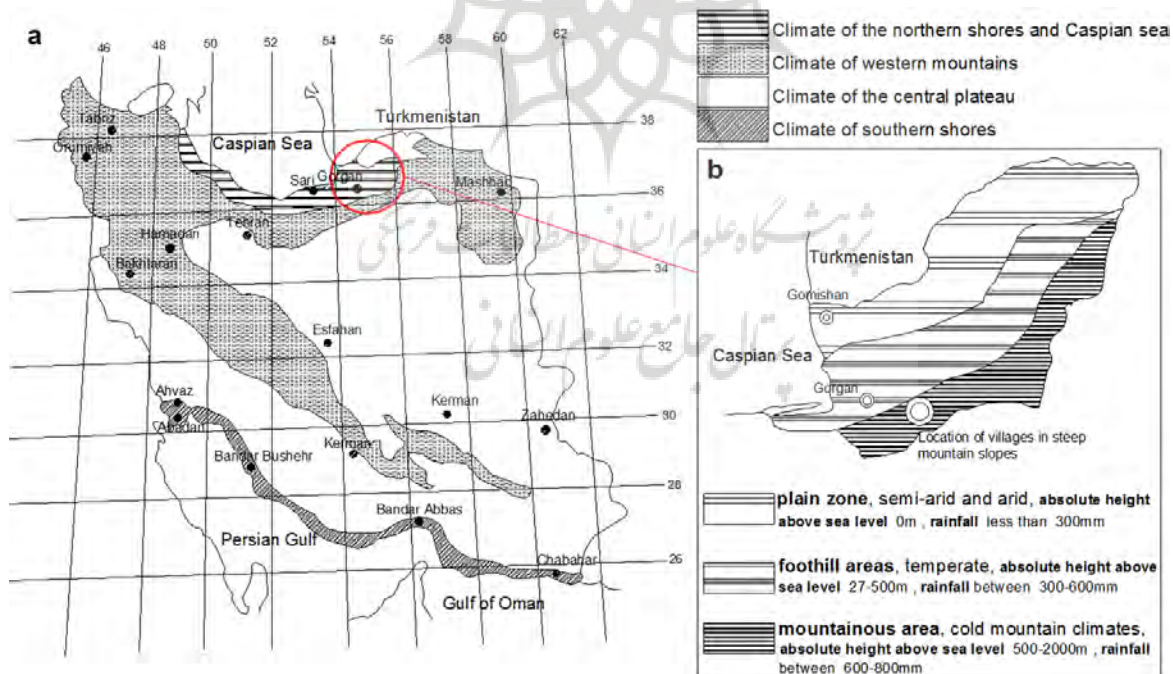

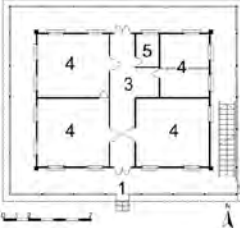
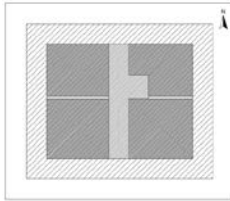

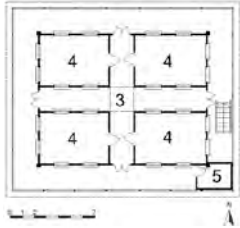

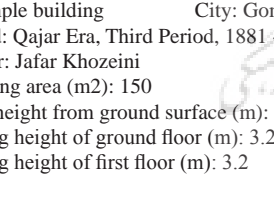
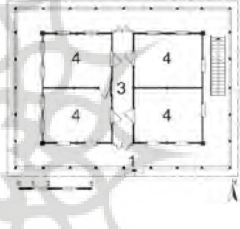
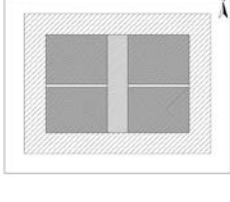

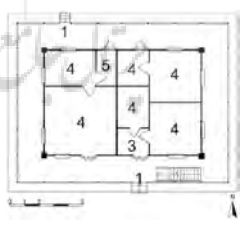
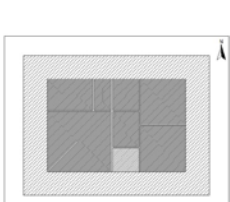

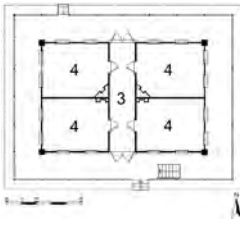
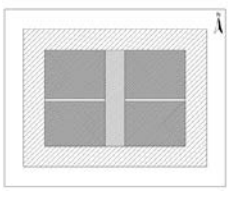









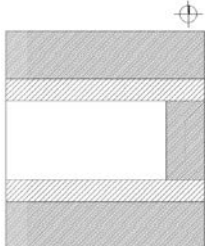
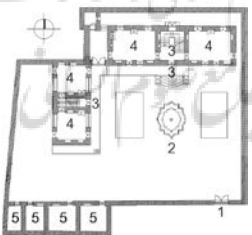
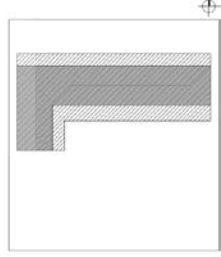
Fig. 2: (a): Map of the range of four climatic zones in Iran, in which the state of Golestan has been specified, taken from studies done for the red crescent by Behrooz Pakdaman, 1357 (Kasmai, 2006); (b): Golestan map, showing the scope of three climatic zones, altitude code and the amount of rainfall of each scope (Shabani et al., 2006).

Table 1. Vernacular architecture type in Gomishan, in the plain zone.

Data	Typical Plan Form	The relationship between open , semi-open and closed spaces
<p>1. sample building City: Gomishan Period: Qajar Era, Third Period, 1881 - 1925 Owner: Bahram Mohammad Khozeini Building area (m2): 270 Roof height from ground surface (m): 7.61 Ceiling height of ground floor (m): 3.28 Ceiling height of first floor (m): 3.73</p> 	 <p>Ground floor</p>	 <p>Ground floor</p>
<p>2. sample building City: Gomishan Period: Qajar Era, Third Period, 1881 - 1925 Owner: Abdol Jabar Khozeini Building area (m2): 165 Roof height from ground surface (m): 7.5 Ceiling height of ground floor (m): 3.5 Ceiling height of first floor (m): 3.5</p> 	 <p>First floor</p>	 <p>First floor</p>
<p>3. sample building City: Gomishan Period: Qajar Era, Third Period, 1881 - 1925 Owner: Jafar Khozeini Building area (m2): 150 Roof height from ground surface (m): 7 Ceiling height of ground floor (m): 3.2 Ceiling height of first floor (m): 3.2</p> 	 <p>Ground floor</p>	 <p>Ground floor</p>
<p>3. sample building City: Gomishan Period: Qajar Era, Third Period, 1881 - 1925 Owner: Jafar Khozeini Building area (m2): 150 Roof height from ground surface (m): 7 Ceiling height of ground floor (m): 3.2 Ceiling height of first floor (m): 3.2</p> 	 <p>Ground floor</p>	 <p>Ground floor</p>
<p>3. sample building City: Gomishan Period: Qajar Era, Third Period, 1881 - 1925 Owner: Jafar Khozeini Building area (m2): 150 Roof height from ground surface (m): 7 Ceiling height of ground floor (m): 3.2 Ceiling height of first floor (m): 3.2</p> 	 <p>First floor</p>	 <p>First floor</p>

Legends: 1: Entrance; 2 – Courtyard; 3 – Corridor; 4 – Room; 5 – Bathroom; – closed space; – semi-open space; – open space. (Plans are redrawing of the plans of Cultural Heritage Documents of Golestan province).

Table 2. Vernacular architecture type in Gorgan, in the mountain foot area.

Data	Typical Plan Form	The relationship between open, semi-open and closed spaces
<p>1. sample building City: Gorgan Period: Pahlavi One, 1925 - 1941 Owner: Hossein Taghavi Building area (m²): 2000 Roof height from ground surface (m): 8.5 Ceiling height of ground floor (m): 3.5 Ceiling height of first floor (m): 3.2</p>	 <p>Ground floor</p>	 <p>Type 1</p>  <p>Type 2</p>
<p>2. sample building City: Gorgan Period: Pahlavi One, 1925 - 1941 Owner: Bagheri Building area (m²): 3000 Roof height from ground surface (m): 8.5 Ceiling height of ground floor (m): 3.5 Ceiling height of first floor (m): 3.2</p>	 <p>Ground floor</p>	 <p>Type 1</p>  <p>Type 2</p>
<p>3. sample building City: Gorgan Period: Qajar, 1863 - 1864 Owner: Mofidian Building area (m²): 415 Roof height from ground surface (m): 8 Ceiling height of ground floor (m): 3.5 Ceiling height of first floor (m): 3</p>	 <p>Ground floor</p>	 <p>Type 2</p>
<p>4. sample building City: Gorgan Period: Qajar, 1863 - 1864 Owner: Fatemi Building area (m²): 1200 Roof height from ground surface (m): 7.4 Ceiling height of ground floor (m): 3.2 Ceiling height of first floor (m): 3</p>	 <p>Ground floor</p>	 <p>Type 2</p>

Legends: 1: Entrance; 2 – Courtyard; 3 – Circulation space; 4 – Residential space; 5 – Service space; – closed space; – semi-open space; – open space. Source for the plans used in the table: (Ghazbanpour, 1993; 1997).

in extrovert shapes, with two floors connected by a staircase. Access to rooms was often through the hallways and central dividing spaces which are linked to terraces. In some cases, rooms and ground floor walls are not followed by the upper floor walls, so the spaces in the ground floor can be less or more those on tin comparison to those in upper floors (Table 1).

The Characteristics of Vernacular Architecture in Gorgan, in the Mountain Foot Area

In fact Gorgan nature is mixed of south border of Mazandaran Sea and north of Alborz mountains chain. Undoubtedly the most important effect of such nature, from emotional aspect and regardless of climatologic issues, is drawing human's attention toward exterior environment and extraversion (Khatibi, 2012). Most of these houses have central yards. The rooms have been built around this central yard. Some of the houses consist of two sections; one an inner house or woman's quarter and the other was the outer one. Their spaces also were divided into two sections of summer living zone and winter living zone to take advantage of sun's heat in winter. The constructed spaces in some of the houses are matched with models of extrovert houses where a built area was surrounded by spaces on its four sides (Table 2).

The Characteristics of Vernacular Architecture in Villages Located in Steep Mountain Slopes

The houses in this area were built in two floors where the lower floor was allocated to service function like storages and the upper floor was allocated to the place of residence. Regarding the space division, there is a place for cooking and setting fire in each room. The plans of these houses were linear and rooms were arranged in a line (Table 3).

Evaluation of Climatic Function of Building Envelope

The evaluation is based on the design variables proposed by Mahoney¹, introducing some building characteristics of vernacular housing that was used to responde to the climate. These tables propose a climate analysis sequence that starts with the basic and monthly available climatic data of temperature, humidity, and rainfall (Khoshsima et al., 2011). These are: a) the layout of the buildings (orientation in relation to sunshine and wind, aspect ratio); b) spacing; c) Ventilation; d) openings (size-position, protection); e) walls (materials-thickness); f) roofs. The following is a summary of the recommendations. Recommended specifications for southern shores of Caspian sea region including Golestan province: a) Layout: orientation north and south (long axis east-west); b) spacing: open spaces for breeze penetration, but protection from hot and cold winds; c) Ventilation: rooms should be single banked with permanent provision for ventilation; d) openings: medium level of openings, 25-40%; protection of openings: protection from rain; position of openings: in windward side at body height; e)

walls: light walls, low thermal capacity, short time lag; f) roofs: light, insulated roofs (Ibid).

Materials and Specific Detailing Used in Building Envelope

The materials using in building envelopes can be generally divided into two categories: massive and lightweight. Examples of massive wall construct materials include rubble and earth, wood covered with packed earth, rammed earth, adobe bricks, large wood timbers, and large stone with earth or mortar as the binding agent. On the contemporary are non-massive, lightweight structures made with thatch, wood, bark or bamboo. It should be noted that many vernacular dwellings observed, combine massive walls with lightweight roofs, most frequently thatch roofs. When the climate becomes hotter and more humid, lightweight building envelopes and materials become more prevalent (Zhai & Previtali, 2010). Because of the ability of massive materials for storing and reradiating heat, as well as reducing conduction by creating a tight envelope, they were the most common vernacular style observed in cold climates and in climates with extreme diurnal temperature variations (Ibid).

Walls

Thick walls made of locally accessible materials such as adobe, stone and large wood timbers, are the most common external walls in the rural houses of mountain slopes. The wall section has a thickness of 30 to 70 cm reduced from ground floor to upper floors and it plays as a good insulator. The time lag of these walls is high; they store heat during the daytime and radiate it into the room at night when the outside temperature is below the comfort range. The light colored surfaces of the facades are used as a mechanism for the protection of the high thermal mass walls against solar radiation as they absorb less heat in summer, thus it prevents the rise of internal temperatures (Maria, 2009).

Traditional houses of mountain foot region are in massive structure group. Thick walls made of brick and Sarooj mortar are the most common materials used in external walls of this zone. The wall section has a thickness of 50-60 cm and it serves as a good insulator. There are wooden columns with 4*6 cm dimensions and height of 3 meter to keep the timbers safe in place (Table 4 and 5). There is more humidity and higher temperature in the plain zone, because of the height below sea level and being close to Turkmenistan deserts and Caspian Sea. In this type of climate, the thermal inertia of the buildings offers no advantage, since the variations in the outside temperature in the daily and annual cycle are very small (Coach, 1998). In vernacular housing of this region, lightweight structure is utilized. The most common material used in this region is the wooden-framed structures. These houses are constructed by local materials, especially wood. The most important advantage of using wood in most parts of these buildings is toughness and

Table 3. Vernacular architecture type in the villages located in steep mountain slopes.

Data	Typical Plan Form	The relationship between open , semi-open and closed spaces
<p>1. sample building Olestan Village Owner: Osta Eisa Building area (m2): 65 Roof height from ground surface (m): 4.5 Ceiling height of ground floor (m): 2.5 Ceiling height of first floor (m): 2</p>	<p>First floor</p>	
<p>2. sample building Olestan Village Owner: - Building area (m2): 77 Roof height from ground surface (m): 4.5 Ceiling height of ground floor (m): 2 Ceiling height of first floor (m): 2.5</p>	<p>First floor</p>	
<p>3. sample building Cheli Sofla Village Owner: Nazari Building area (m2): 69 Roof height from ground surface (m): 5.5 Ceiling height of ground floor (m): 3 Ceiling height of first floor (m): 2.5</p>	<p>First floor</p>	
<p>4. sample building Cheli Sofla Village Owner: Kheir Allah Nazari Building area (m2): 31 Roof height from ground surface (m): 4.8 Ceiling height of ground floor (m): 2 Ceiling height of first floor (m): 1.8</p>	<p>First floor</p>	
<p>5. sample building Cheli Sofla Village Owner: Vali Allah Nazari Building area (m2): 102 Roof height from ground surface (m): 5.8 Ceiling height of ground floor (m): 1.8 Ceiling height of first floor (m): 2 Ceiling height of second floor (m): 2</p>	<p>First floor</p>	

Legends: 1: Entrance; 2 – Courtyard; 3 – Circulation space; 4 – Residential space; 5 – Service space; – closed space; – semi-open space; – open space.

Table 4. Average temperature of inner and outer surface of southern walls in comparison to the outside temperature in the summer.

Typology	Floors	average temperature (Centigrade degree)			difference in temperature of the two sides of the wall
		outside the building	inner surface of the wall	outer surface of the wall	
Buildings in plain and flatlands		In the shadow at 16:40 pm:33 c			
	Ground floor		30.05 c at 4 to 5 pm	31.45 c at 4 to 5 pm	1.4 c
	First floor		31.2 c at 4 to 5 pm	32.7 c at 4 to 5 pm	1.5 c
Buildings in mountain foot region		In the shadow at 1:47 pm:34.7 c			
	Ground floor		29.3 c at 1 to 2 pm	31.7 c at 1 to 2 pm	2.4 c
	First floor		30.3 c at 1 to 2 pm	34.2 c at 1 to 2 pm	3.9 c
Buildings in steep mountain slopes		In the shadow at 1pm:30.3 c			
	Ground floor		24.9 c at 1 to 2 pm	27.3 c at 1 to 2 pm	2.4 c
	First floor		25.65 c at 1 to 2 pm	29.05 c at 1 to 2 pm	3.4 c

hardness of wood, its robustness against humidity and weak thermal conductivity (Singh et al., 2009). Buildings' walls are wooden and the timbers are used in cross form, with thickness of two centimeter for better absorbency of mortars on external body. On first floors of the buildings for covering the walls, plaster of sea, sand and lime mortar has been used. Column and timber joints are groove and key form and dimensions of wooden columns are 30* 30 cm (Table 4 & 5).

Roofs

In the mountain foot region, massive materials with high thermal capacity are used in walls while roof materials have medium thermal capacities. In Houses of Gorgan, located on hillside, wooden dicer timbers and mud hammer form the ceiling. In order to increase the heat capacity of the roof, tiled roofs are always employed by mud in fills. Disadvantage of

vernacular housing in steep mountain slopes is the weak ceiling insulation. The traditional material of clay and recently popular materials used in the ceilings doesn't work properly. In plain zone of Gomishan city, using lightweight buildings, with low thermal capacity and the possibility of ventilation inside the roof structure, via the little doors that are built in the ceiling, result to keeping less heat in the ceiling. Pitched roofs, usually in three layers, have been made of tin layers and supported by wooden trusses and rafters (Table 5).

Layout

Orientation
 The dwellings have been shaped on a long east-west axis. But In the vernacular houses of Gorgan, we can see the same orientation in a different way. In houses of Taghavi and Bagheri, spaces are divided into interior and exterior while living spaces

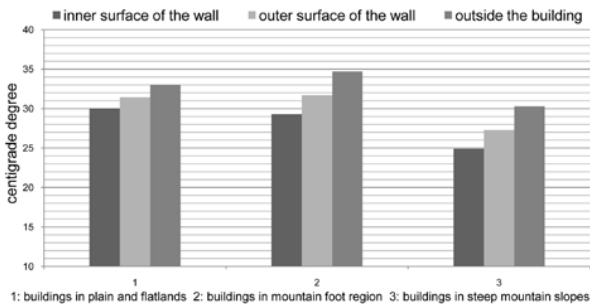


Fig. 3: Ground floor S walls, in the summer noon

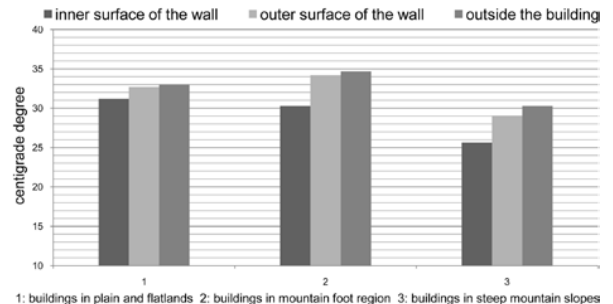


Fig. 4: First floor S walls, in the summer noon

have been arranged around the main yard. The east-west elongation of the building, create summery and wintery parts. In Fatemi's house, the plan stretched in center of the yard on a long east-west axis, like the samples in other zones (Table 5).

Aspect ratio

The term "aspect ratio" is used to denote the ratio of the longer dimension of a rectangular plan to the shorter one. The N and S walls are longer than E and W, so the "aspect ratio" varies from 1.2 to 3.0 (Table 5). In vernacular architecture of Gomishan, in the plain zone, the ratio of length to width is less. Therefore, plans have become closer to the shape of square. The ratio of length to width in vernacular architecture in steep mountain slopes, are more than the other examples (Table 5).

Ventilation

Provision of fresh air: The rooms of these dwellings benefits from the natural ventilation. The appropriate placement and size of the openings help to taking advantage of breezes. The Mahoney tables suggest that rooms should be single banked with permanent provision for air movement. Contrary to this suggestion, the plan of the dwellings in the plain scope of the study is double-banked but the axial corridor provides wind passage (Table 5). In the plain zone and houses of mountain foot region in Gorgan, the wooden external shutters are often used to control natural ventilation. In addition, they are able to control the sunlight. In the plain zone, there is also provision for ventilation in the empty space between the ceiling and the roof that adds to the overall cooling (Table 5).

Openings

Size-position of openings: Opening placement depends on sun orientation, topography, views, and wind patterns. The size and proportion of openings is determined by the orientation of the walls. Thus optimum views, benefiting natural lighting and breezes are achieved with suitable orientation and proportion of the openings as well as their juxtaposition. In the plain zone, there are several N and S openings in big sizes whereas those of E and W are fewer and smaller. The houses of foothills region in Gorgan have multiple openings in all internal levels from the central yard, while in front of the out of the building and the alley, openings are fewer in ground floor but more in first floor. In the mountainous region, due to cold weather, the size of openings is much less than those of other two zones. In this zone, fewer number of small windows facing north and south facades and their placement on this N to S axis, depends on the direction of prevailing breezes in the summer (Table 5).

Protection of the openings: Protection of the openings from solar radiation during summer, especially in the plain zone and mountain foot region, is provided by using movable shades such as wooden external shutters that permit the dwelling to be fully shaded during the summer but fully exposed to solar radiation in the winter. Such devices are: blinds and lattices, curtains, vertical shafts, external horizontal shades,

and shutters. Openings play a key role in facilitating thermal comfort of dwellings with high thermal inertia walls. Verandas and the external shutters on summary parts of the sample houses are architectural components with various forms, which are creating complete shade on the sun-warmed facades, changing the ventilation, and protecting from rain exposure. They are usually North and south oriented, preventing thermal transition from inwards to outwards (Table 5, 6).

Base Course and the Contact of Building with the Ground

for preventing from earth moisture penetration to the residential spaces, in all three regions, base course were built but these base courses varies in these three zones:

The houses in plain zone are constructed approximately 60 cm high above the ground. This height not only prevents moisture penetration to the building but also allows air flow under the shell of the building floor and helps to control the temperature. In all of the samples of Gorgan, in mountain foot area, base course are as a platform. Under the rooms of ground floor, there is an empty space which have almost 1 meter height above the ground. This method is used to prevent moisture penetration to the building but unlike plain zone, there is no free air flow in this section.

In the vernacular architecture of mountainous scope, ground floor has been used as food storage and the residential functions are above the ground floor. So ground floor plays as a barrier to prevent the moisture gets into the building and the height of living spaces helps to taking advantage of good wind and ventilation in both hot and cold seasons. The air between shells of residential section's floor and ground floor, acts as an insulator against the cold ground.

Roof Types and Eaves

Generally, in vernacular architecture of humid regions, roof is a very important element, since it has to act as a parasol and umbrella at the same time (Coach, 1998). Because of the excessive amount of rain, the roofs of the vernacular houses in all three areas are very inclined. Among the many types of the roofs, the most common ones are the saddle roof and hipped roof. Hipped roofs may have three or four pitches. It was observed that large eaves were used in all houses in the region, especially in the plain zone and houses of mountain foot region in Gorgan. The functions of the eaves are to protect the wall surface against the rain besides providing temporary storage for households and agricultural tools. In the studied units of mountainous areas, the roofs were often double-pitched or triple-pitched. Considering colder weather of this area, the eaves' width are shorter in order to providing less shading in southern and northern shells of the building aiming to storing and absorbing the heat of sun in cold winter, and preventing against the strike of rainfall to the building. In under study buildings of foothill area, the three section (three cracks) roof eaves, have been used because it is suitable for shading,

Table 5. Evaluation of the architectural typology and building physics.

Type/sample	Layout	Orientation	Aspect ratio	Spacing	Air movement	Openings	Protection	Walls	Roofs
Plain	1		1.2	Detached Extensive courtyard	Double-banked Axial corridor	N & S: 47% E & W: 40%	External wooden shutters Veranda at all sides	Wooden walls of low thermal mass	Roofs of low thermal mass
	2		1.3	Detached Extensive courtyard	Double-banked Axial corridor	N & S: 32% E: 18%, W: 27.5%	External wooden shutters Veranda at all sides	Wooden walls of low thermal mass	Roofs of low thermal mass
	3		1.3	Detached Extensive courtyard	Double-banked Axial corridor	N & S: 40% E & W: 35%	External wooden shutters Veranda at all sides	Wooden walls of low thermal mass	Roofs of low thermal mass
Mountain foot	1		2.5(average summery and wintery parts)	internal courtyard	Single-banked	N & S & E & W to the courtyard: 43% N & S to the alley: 7%	Veranda at the N. side Large eaves External wooden shutters	Adobe-brick walls of high thermal mass	Roofs of medium thermal mass
	2		2.8 (average of summery and wintery parts)	internal courtyard	Single-banked	N & S & E & W to the courtyard: 34% N & S to the alley: 5%	Veranda at the N. side Large eaves External wooden shutters	Adobe-brick walls of high thermal mass	Roofs of medium thermal mass
	3		2.8 (average of summery and wintery parts)	internal courtyard	Single-banked	N & S to the courtyard: 43% S to the alley: 6%	Veranda at the N. side Large eaves External wooden shutters on summery parts	Adobe-brick walls of high thermal mass	Roofs of medium thermal mass
	4		3	Detached Extensive courtyard	Single-banked	N & S: 28% E & W: 22%	Balcony at the S. side Large eaves	Adobe-brick walls of high thermal mass	Roofs of medium thermal mass
Steep mountain slopes	1		1.8	Open spaces from two sides	Single-banked	N & S: 11% W: 5%	Veranda at both N. & S. sides	Adobe-stone walls of high thermal mass	Roofs of low thermal mass
	2		2	Open spaces from two sides	Single-banked	N & S: 14% W: 3%	Veranda at both N. & S. sides	Adobe-stone walls of high thermal mass	Roofs of low thermal mass
	3		1.6	Open spaces from two sides	Single-banked	N: 5% S: 11% E: 7%	Veranda at both N. & S. sides	Adobe-stone walls of high thermal mass	Roofs of medium thermal mass
	4		2	Open spaces from two sides	Single-banked	N & S: 5% W: 5%	Veranda at both N. & S. sides	Adobe-stone walls of high thermal mass	Roofs of low thermal mass
	5			Open spaces from two sides	Single-banked	N: 4% S: 9% W: 2%	Veranda at both N. & S. sides	Adobe-stone walls of high thermal mass	Roofs of low thermal mass

Table 6. Veranda position and proportions

Typology	Buildings in plain and flatlands			Buildings in mountain foot region				Buildings in steep mountain slopes				
	1	2	3	1	2	3	4	1	2	3	4	5
Balcony position	all around	all around	all around	Around the central yard	Around the central yard	east-west along the wintery part	east-west	east-west	east-west	east-west	east-west	east-west
Width of veranda and balcony	2.2 m	2.1 m	2.3 m	1.2 m	1.2 m	1.5 m	1.2m	0.9m	1.6m	1 m	0.9m	1.2 m
ratio of veranda's area to whole of the building	0.45	0.46	0.49	0.1	0.06	0.04	0.04	0.3	0.33	0.35	0.32	0.37

preventing rainfall from hitting the body of building as well as haing a decorative aspect. The width of the eaves of roofs is shorter than the ones in plain zone while longer than ones of mountain zone.

Veranda

Verandas in vernacular houses of Gomishan in plain zone have more width in comparison to the other two regions. They are stretched all around the building in a uniformed way and roof has been covered over the veranda like a widespread umbrella. Therefore, another layer of space is placed in front of the building's body which protects the building envelope from sun light and strike of rainfall. So residents enjoy a suitable space where is in shadow and has the possibility of air flow around it (Table 6).

The width of veranda in vernacular houses of Gorgan in mountain foot region is shorter than the buildings of plain region that has been used for shading and connecting the different sections of the building. They are located all around the central yard and in some types along the east-west tendency of the building from two sides.

The units located in mountainous regions, in most cases, have two columned verandas in northern and southern fronts of the building. The width of veranda in this region is shorter than the units located in plain and mountain foot regions (Table 6).

CONCLUSION

In the north of Iran, Golestan fits in moderate and humid zone and the characteristics of its vernacular architecture is common in some aspects. Use of pitched roofs, veranda, extending height and base course, east-west elongation of buildings, open plan and two- way ventilation, are common climatic features in this region. The results of the research show that with a closer look, the local environment and microclimates have been addressed properly in vernacular architecture of each scope of the region. They follow suitable climatic solutions, which are consistent with the Mahoney's recommendations. Followings

are the conclusions of the investigation in each climatic scope: The building envelopes in Gomishan region, in the plain zone, are designed especially for the hot and humid seasons. In all samples of this region, lightweight structures have been used and the main material used in body is wood which is tough, hard and has resistance against region's high humidity with low thermal refuge. Open plan helps to take the advantage of local winds for better ventilation inside the building. Therefore larger and more windows have been used. Openings have been located on all four sides. Thus the form of the plan has become closer to the square shape than a rectangle shape with east-west elongation. The brick base course helps wind blowing under the floor shell which is a suitable solution for preventing the earth's moisture penetration to the building. Wider verandas and eave of the roof have been employed for shading purposes. At the same time, windows have controllers against sunlight, thus the building envelopes are protected from sunlight.

In the case studies of mountain foot region in Gorgan, with moderate weather and lower humidity, massive wall materials have been utilized. Ceilings, timbers and decorations are made of wood. The sample plans of this scope show that spaces are being arranged around the main yard. But the use of dual ventilation with east-west tendency of major residential spaces and creation of multiple openings overlooking the internal yard, especially in front of south (winter living) and north (summer living), are seen in all studied samples. In addition, width of veranda and eave of the roof are shorter than the plain zone.

. In studied samples of mountainous region, with lower temperature and cold winters, the height of buildings are less and for using more heat of the sun, there is more emphasis on massive structures and materials with higher thermal capacity. In these units, the proportion of length to width, have been increased. On the other hand, width of the shade and verandas and also areas of the openings have been reduced to a great extent. Besides, the orientation of openings on northern and eastern sides and the status of residential parts in upper ground floor, provide the

possibility of better ventilation in warm seasons.

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All photos of this paper have been prepared on the field studies by the author. Plans of residential units of plain zone are redrawing of plans of Cultural Heritage documents of Golestan province. While the plans of residential units of mountain foot and Gorgan are redrawing of current plans in two books of New Living-Old Body and Iranian Home. Plans of residential units of mountainous zone have been drawn for this research by the author.

ENDNOTES

1. Mahoney tables are a set of reference tables used as a guide to climatic design which have been proposed by Mahoney (1968) and developed by Konigsberger.

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