Architectural Structure and Environmental Performance of Sustainable Lahijan Vernacular Settlements, N Iran

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***Abstract*- Vernacular residential structures of Lahijan located in north of Iran "Shikili Houses" can be considered as living organism which are the inheritance of optimal use of materials, constructing methods and climatic considerations during centuries. In this study, architectural documents and climatologic properties of around 26 types of wooden houses remained from 20th century in this city are analyzed. Besides, a combination of existing environmental parameters which result in creation of special characteristics in order to make desirable requirements suitable for micro-climate considered is studied. The combination mentioned can be called "Sustainable Design" which means 'utilizing suitable technology and designing principles with a wise and intelligible approach toward climate and environment'. This kind of design is based on the layout of the building (orientation in relation to the sun and the wind, aspect ratio), the spacing (site planning), the air movement, the openings (size – position, protection), and the building envelope (walls: construction materials-thickness, roof construction detailing). The aim of the study is to document and assess, both qualitatively and quantitatively, all the afore-mentioned aspects in order to draw conclusions concerning the principles, which have characterized this architecture and can be integrated to the refurbishment of existing buildings or the design of new ones in traditional surroundings.**

***Keywords*- Vernacular architecture; North Iran; Bioclimatic design; Construction techniques; Building physics**

I. INTRODUCTION

The vernacular buildings in every area are a product of the accumulated experience and practice of many centuries and can constitute a continuous source of knowledge [ ]. With regard to this point, it can be claimed that these buildings are designed in accord to bioclimatic. Bioclimatic design, by definition, satisfies the needs of human beings (thermal, luminous and acoustics) [ ]. It considers climatic conditions, uses techniques and materials available in the region and attempts to integrate the building with its surroundings which contribute to the distinct architectural identity of every area. This is the main reason why various researchers have examined traditional and vernacular buildings throughout the world with respect to bioclimatic and environmental architecture.

Moreover, bioclimatic design relies on building physics, which is the ability and knowledge of how to allow sunlight, heat, and airflow through the building envelope when necessary, at certain moments of each day and month of the year [ ]. The vernacular architecture of Lahijan may be defined as bioclimatic since, it can be argued, the traditional builders of Lahijan understood bioclimatic concepts, aspects of building physics, and the strong relationship between site, climate and building that made them aware of the consequences of design choices [ ].

This study is mainly based on a large-scale in situ research, which included the documentation of twenty six (26) vernacular buildings (in Table 3 of the 26 houses are presented due to restrictions of space and format). These building are actually the only ones that have remained from the roundabout of the 20th century. From this research, data concerning the typology, the form, the materials and the construction techniques of the buildings are presented. Bibliographic research is also used for the presentation of the general data of the studied area (geographic location, climate, topography, ground composition, historical data), which, due to the restricted size of the paper, are briefly presented.

Finally, conclusions are drawn in order to outline the design principles, which have characterized this architecture and can be related to bioclimatic architecture [1].

II. GENERAL DATA ON GEOGRAPHY AND CLIMATE

A. Geographic Location

Lahijan town is located in the East area of Gilan (a county North of Iran) and between the Caspian sea and Alborz mountain (Fig. 1). The town area is 584.3 km^2. The longitude of the town is 49°45´14´´ East, its latitude is 37°11´24´´ North, and its altitude is -2 m [ ].

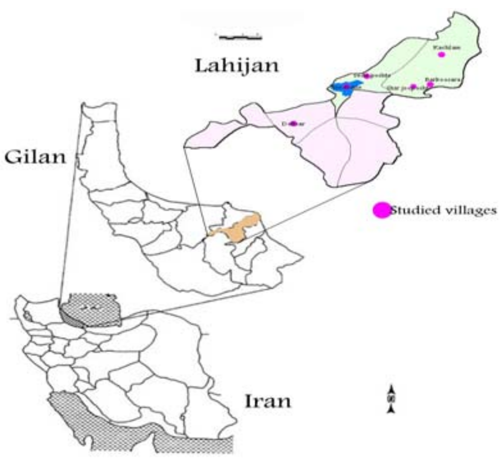


Fig. 1 Iran, Gilan , Lahijan and the studied

B. Climatic Data

Since the city is located between Caspian Sea and Alborz mountain range which are covered by jungle. It has a nice weather and during summer due to sever evaporation, the weather is heavy for some time and moisture results in summer showers in heights. At the same time in plains the air pressure is low and the temperature is high and winds blow from sea to the beach (Table 1 [ ]).

TABLE I MONTHLY CLIMATIC DATA VALUES FOR LAHIJAN DERIVED FROM THE YEARS 1999 E 2004

	Winter			Spring			SUMMER			Autumn		
	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV
Mean min temp(℃)	5.33	3	2.8	5.5	8.7	13.3	17.06	19.4	19.84	17.38	13.46	9.04
Average temp (℃)	10.17	7.60	7.65	9.85	14.30	18.70	22.53	24.85	24.92	22.09	18.03	13.77
Mean max temp (℃)	15.0	12.2	12.5	14.2	19.9	24.1	28.0	30.3	30.0	26.8	22.6	18.5
Rel. humidity (%)	79	79	78	79	76	76	72	72	75	80	82	80
Aver. rainfall (mm)	163.2	126	117.8	126.1	76.1	57.1	59	50.2	68.7	166.6	232.3	187.7
Days of rain	11	11	10	11	8	7	5	4	6	10	12	11
Wind direction	SW	SW	SW	SW	W	E	E	E	S	E	S	SW
Wind speed (m/s)	8	8	8	8	18	12	8	6	6	6	7	10

The mean maximum temperature in December reaches 15°C; the average temperature is 10.17°C, while the mean minimum temperature is 5.33°C. The mean maximum temperature in January reaches 12.2°C; the average temperature is 7.6°C, while the mean minimum temperature is 3°C. The mean maximum temperature in February (coldest month of the year) reaches 12.5°C; the average temperature is 7.65°C, while the mean minimum temperature is 2.8°C. The corresponding relative humidity values are 79% for December, 79% for January, and 78% for February. Lahijan has relatively high precipitation values during the winter period, with an average value of 163.2 mm for December, 126 mm for January, 117.8 mm for February and about 11 days of rain per winter month. The direction of the prevailing winds is South-West during December, January and February.

The mean maximum temperature in June reaches 28°C; the average temperature is 22.35°C, while the mean minimum temperature is 17.06°C. The mean maximum temperature in July (hottest month of the year) reaches 30.3°C; the average temperature is 24.85°C, while the mean minimum temperature is 19.4°C. The mean maximum temperature in August reaches 30.0°C; the average temperature is 24.92°C, while the mean minimum temperature is 19.84°C. The corresponding relative humidity values are 72% for January, 72% for July, and 75% for August. Lahijan has relatively medium precipitation values during the summer period, with an average value of 59 mm for January, 50.2 mm for July, 68.7 mm for August and about 5 days of rain per summer month. The direction of the prevailing winds is East during summer month.

According to the above table, Lahijan town has a moderate and humid climate (Csa) and this microclimate is defined as following:

GROUP C: Temperate climates

These climates have an average temperature above 10°C (50°F) in their warmest months, and a coldest month average between −3°C (26.6°F) and 18°C (64°F). The second letter indicates the precipitation patterns indicate dry summers (driest summer month less than 30 mm average precipitation and less than one-third wettest winter month precipitation). The third letter indicates the degree of summer heat, a indicates warmest month average temperature above 22°C (72°F) with at least 4 months averaging above 10°C (50°F) [ ].

III. ANALYSIS OF THE BUILT ENVIRONMENT

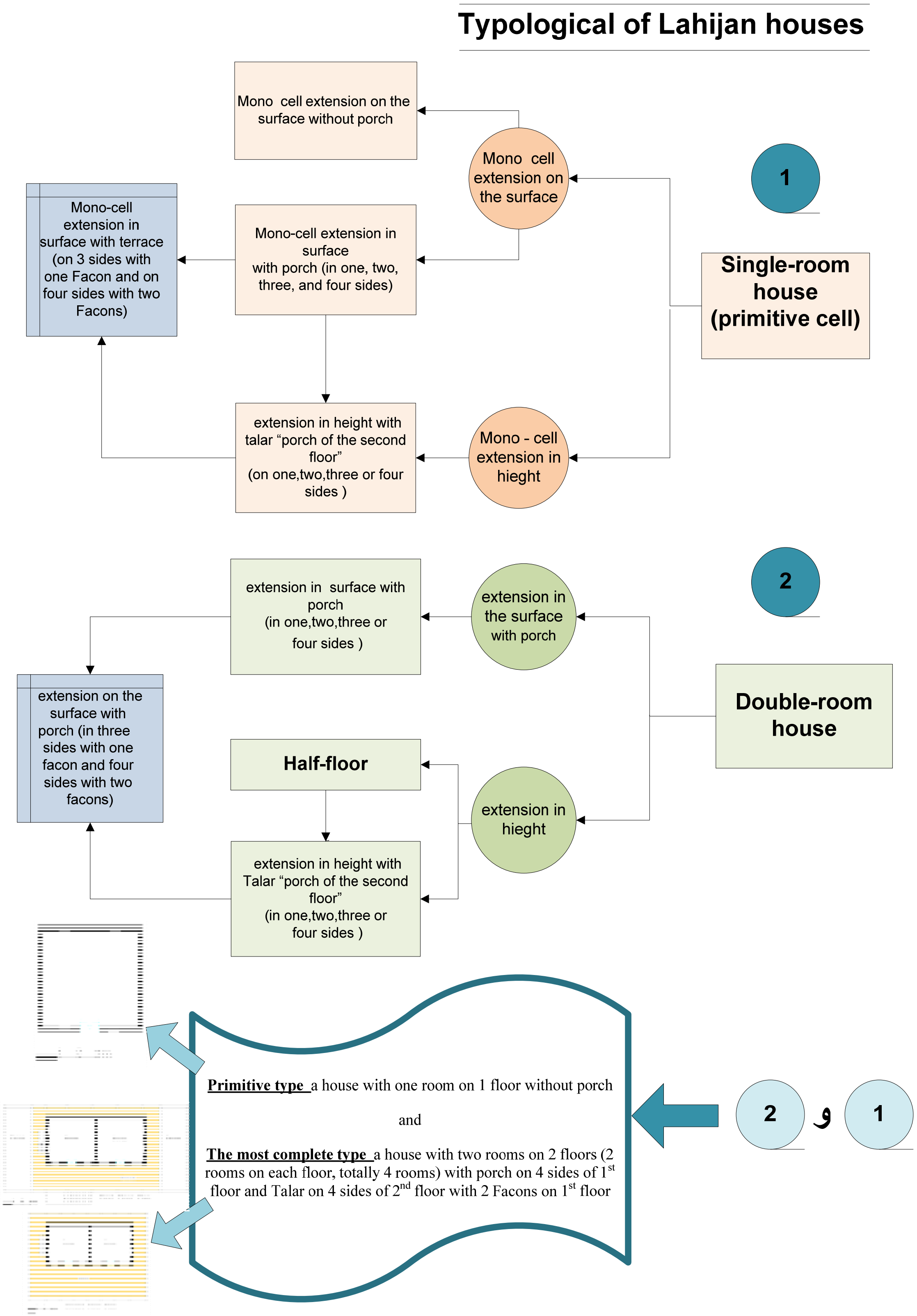
Lahijan has a strong vernacular character of great interest, both morphologically and structurally, with a unique landscape pattern (Shikili houses (Fig. 2)).

This study examines the most important architectural forms found in Lahijan that played a significant role in the evolution of vernacular architecture in Gilan and which are subject to preservation. The collected data are the outcome of personal field work, i.e., the author measured, sketched, observed, and interviewed inhabitants, local designers as well as public and private experts relating to the energy aspects of the buildings.

A. Typological Analysis

In Lahijan's micro-climate, the types were completed gradually and based on the needs of population growth. Houses are the results of a cooperation among different generations also builders and owners of the houses. In Lahijan, we can see general plan of houses and simple form of buildings in combination with architectural and structural elements. Two main issues i.e. simple forms and extensive courtyards are observable in all types. The research about local houses of Lahijan resulted in the identification of 4 main types of buildings and changes related to them. These 4 kinds, (one or double-storey mono cellular, one or double-storey double-room) can be described in the form of Table 2.

TABLE II TYPOLOGICAL OF LAHIJAN HOUSES



B. Site Planning

Shakili houses of Lahijan developed in response to orientation, wind direction, and topography (Fig. 3). Detached houses with extensive courtyards are located in rice fields and roundabout streets with different widths, shapes and locations connect buildings to each other (Fig. 4).

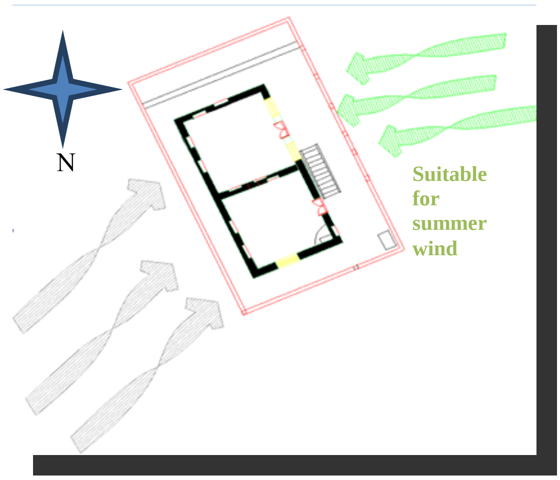


Fig. 3 Proper orientation of buildings, suitable for summer wind and protection from undesirable winter winds

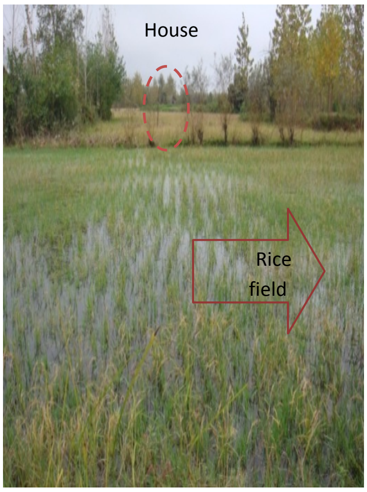


Fig. 4 The detached houses in the middle of rice field

A number of relationships and size ratios between streets and houses are recorded (Fig. 5), all indicative of the human scale of the settlement (Fig. 6) as for the private gardens, they are pleasant spaces where outdoor activities take place almost throughout the year. Dwellings gardens have developed in harmony and interdependence. These spaces are walled by fences which define limits of residential space and are a guard for quadrupeds and poultries. Depending on the place, fences can be of reeds woven by thin twigs (today metal strings are used instead of these twigs) or branches fastened around a stand or horizontal woods fastened on a beam in peripheral spaces including gardens, rice fields, stables, etc.

Fig. 5 Relationships and size between streets and houses

Fig. 6 The human scale of the settlement

Fig. 7 Defining the boundary between public and private

C. Construction Materials and Techniques

Gilan plain is located between northern foothills of Alborz mountain range and southern coasts of Caspian Sea. The region has a special kind of climate named 'Caspian temperate climate' which is influenced by Alborz Mountains and Caspian Sea. Talesh mountainous with northern-southern direction and Alborz mountainous with eastern-western extension act as a dam preventing the moisture made by Caspian Sea and also wet north-western winds to enter the country and due to their high elevation, they cause vast rainfalls in this region.

All these reasons have brought about rich herbaceous coverings in this area. Thick jungles are more seen in northern skirts and in mountains around cities and trees include: oak, box-tree, olive, birch, beech, alder, etc. This property caused wood and herbaceous materials to be the main construction elements in this region.

In a general look we see that Shikili houses with roofs covered by herbaceous fibers and a slope around 200%, on single-layer rooms fenced by connected wide terraces. These terraces and summer Talar create a see-through layer around building which are located on apparently articulated foundations higher than the ground. The storey and the ground are connected by unilateral wooden stairs which in the main view they show the flexibility of the dwelling, accommodative with nature and present it much lighter. In other words, the building expresses its homogeneity with the environment through porous layers of surface and a height like plants grown from the ground.

The steps of building Shikili houses include:

a) Shikil or Baj baneh

1) Pakekubi (soil bed): after excavation to the depth of 1.5 meters, the hole is filled with charcoal, wood ashes and river sand then they pound them by a wooden sledge and continue this task to the height of 50 cm upper than the ground in order not to let surface run off demolish soil bed. Then they cover it by lime. 2) The next step in constructing Shikili foundation (centralized points) is erecting wooden (4 layered) pillars which raise the building to a specified height to protect it against moisture and flood. 3) Pillars: to build the ground of first floor, 3 main wooden layers which connect floor to the parts of land are used (Fig. 8).

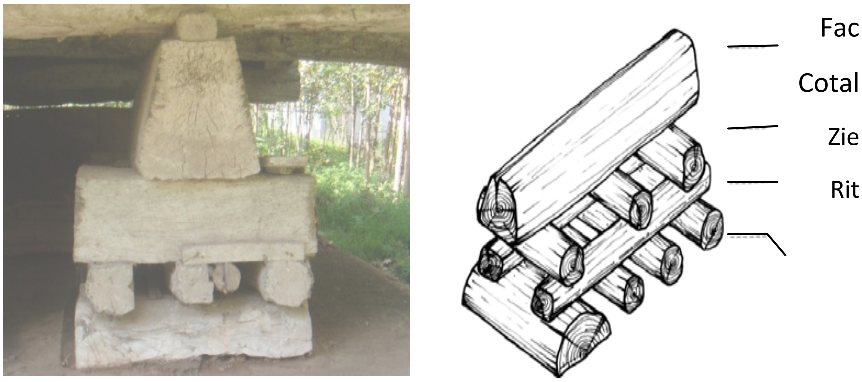


Fig. 8 Foundation components

Fig. 9 “Zagmeii” wall

Undesirable winter winds

b) Vertical surfaces in house architecture: two kinds of vertical surfaces in the form of flat central-point which is rigid and see-through surfaces of external layers of the building are noticeable in the architecture of this region.

Rigid central-point surfaces are the walls. In Lahijan a special kind of “Zagmeii” wall is constructed. The material of these walls is woods attached to each other by bolts and notches. The holes in wooden parts of the wall are filled with cob and it results in relative joint of wooden parts and also prevents them against fungus and termites. Finally, walls are coated with a mixture of water, lime and a little salt.

Next step is building see-through external surfaces which include horizontal and vertical parts of main appearance. Terraces are defined in the distance between see-through surfaces and rigid central- point. Eastward side of the building include beams which are identifies as loading agents parallel to east and westward walls of central point which transfer roof load. The main joints are in loading elements of Viris (a rope made of rice stalks) and in other parts which do not transfer load, pins are used.

c) Inclined roofs: to build an inclined roof, four 12 m straight and long woods of elm-tree are used to construct the main frame. First, they are tied to each other in a triangle form by Viris and are carried on the roof by ropes. Then by long thick woods, four main beams of the roof are erected which sustain all load and weight of the roof. Next, horizontal pillars of the roof which is of tree browses are tied to vertical pillars by Viris and a lattice is provided on the roof. After that, some reeds (a plant which grows in wetland) or rice stalks are shaped in spiral form and put in lattices. Reeds and rice stalks create a porous layer in final cover and they make a very good acoustical and thermal insulator. But they have some weak points as well. They can’t resist against fire and the moss which grow in parts receiving little sunshine. Today, galvanized sheets are utilized in final cover.

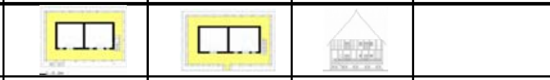
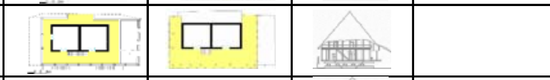
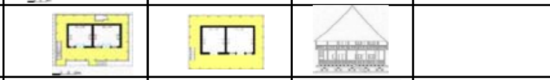
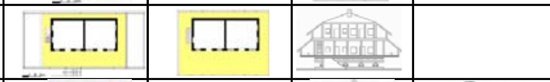
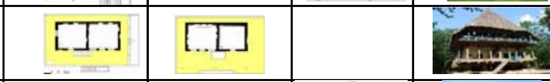
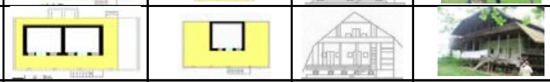
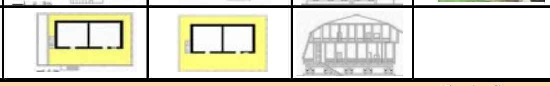
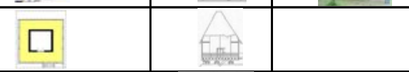
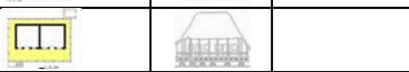
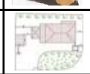
d) Facon: is an architectural element constructed in most local buildings of this region with special applications as service-providing spaces in the directions toward autumn and winter winds and it restrains rain to enter. The space under Facon on the land is suitable for keeping quadrupeds.

IV. EVALUATION

A. Architectural Typology and Building Physics

Vernacular dwellings of Lahijan are evaluated in terms of building physics criteria that pertain to solar geometry, thermal mass, heat transfer, air movement, and solar geometry. Moreover, the evaluation is based on the design variables proposed by Mahoney as the ones that promote the creation of buildings responsive to the climate. These are: a) the layout of the buildings (orientation in relation to sun and wind, aspect ratio); b) spacing (site planning); c) air movement; d) openings (size–position, protection); and e) building envelope (walls: construction materials- thickness, roof construction detailing) [ ] (Table 3).

TABLE III TYPOLOGICAL ANALYSIS

	First Floor plan	Second Floor plan	East Elevation	photo	Site planning		Aspect ratio	Description
Double-floor species								
1					Detached Extensive courtyard		0.28	double-floor buildings, ground floor used in winter, first floor used in summer also for guests wooden stairs outside lead to first floor
2					Detached Extensive courtyard		0.31	
3					Detached Extensive courtyard		0.27	
4					Detached Extensive courtyard		0.35	
5					Detached Extensive courtyard		0.27	
6					Detached Extensive courtyard		0.41	
7					Detached Extensive courtyard		0.28	
8					Detached Extensive courtyard		0.40	
9					Detached Extensive courtyard		0.27	
10					Detached Extensive courtyard		0.37	
11					Detached Extensive courtyard		0.30	
Single-floor species								
1					Detached Extensive courtyard		0.00	Single-floor all activities carried out in one room
2					Detached Extensive courtyard		0.10	
3					Detached Extensive courtyard		-0.17	
4					Detached Extensive courtyard		-0.13	
5					Detached Extensive courtyard		0.28	Single floor with 2rooms, one room for all activities, the other for guests
6					Detached Extensive courtyard		0.30	
7					Detached Extensive courtyard		0.27	
8					Detached Extensive courtyard		0.16	Single-floor with 2rooms, 1 room for all activities the other for guest with Facon for storage
9					Detached Extensive courtyard		0.12	
10					Detached Extensive courtyard		0.31	single-floor with 2 rooms, one for all activities, the other for guests. Another room plotted separately will be attached later
11	Next Accessories				Detached Extensive courtyard		0.34	
12					Detached Extensive courtyard		0.35	

B. Layout

Orientation: Dwellings are oriented on a North West axis. Aspect ratio: The term "aspect ratio" is used to denote the ratio of the longer dimension of a rectangular plan to the shorter. The N/W and S/E walls are longer than the N/E and S/W and the "aspect ratio" is (0.36) or 1 to 3.

C. Spacing

Site planning: Detached dwellings of semi - compact geometry and extensive courtyards are designed considering climate condition [ ] (Fig. 10). Courtyard defines a relationship between the house and passage part outside, it is also a place for daily activities of people in the house such as children's play, cooking in summer, preparing agricultural products (specially rice which is the main product of this region) and garden-grown products for own consumption or offering in market, activities related to farm animals and some other activities like; producing handicrafts. Courtyard is important regarding climate as well, in the way that considering the distance between construction and limit of residential part, sun shine and wind circulation will be possible and it has a huge influence on repelling moisture from construction and making comfort for the person. Besides, courtyard preserves the limits of house and it separates movement paths of human and animals. Regarding culture, courtyard width both protects spatial limits of house and is a place for neighbors to visit each other and exchange information and sustain friendship. Most of the times courtyard is a secondary passage for some neighbors and it makes a kind of easement right.

Fig. 10 Detached dwellings and extensive courtyards

D. Air Movement

High moisture in all seasons is the principle problem of this region; consequently the most important factor of creating comfort in buildings of the region is establishment of durability and draught in them. The task is carried out in this way; buildings are organized in scattered manner in the region, their direction is so that winds from east (suitable summer winds) and the breeze from sea should be applied most and also the direction of undesirable, sever and long winter winds and also inclined rains are blocked completely.

Plans have a wide and open design and their frame is narrow in geometrical shapes. Porches and Talar (the porch in second floor which are exposed to wind and contain better draught) (Fig. 11) are located in four sides of the building and makes easy movement of wind in residential floors possible. Suitable and natural ventilation of rooms is practical by establishment of openings in appropriate places to receive breeze with the amount related to the room size. So the building is detached from the land and ventilation takes place in the section under the building as well.

Fig. 11 Talar (The Porch in second floor)

E. Openings

Size–position of openings: Openings are placed according to sun orientation, topography, views, and wind patterns. Their types, proportions and sizes are determined by the orientation of their wall. Thus, optimum views, natural lighting and cooling breezes are achieved with suitable orientation, design and geometry of the openings as well as their juxtaposition [2]. Older types lack any window. This issue shows the extroversion in this region. Additionally, in the past due to the lack of the media, staying in the rooms with beautiful and wide yards available has been nonsense.

After analyzing the results for the types studied, these conclusions are made:

1. Openings in single-storey buildings (doors), around 93% in eastward view and 7% in southward view and (windows) around 63% in eastward view and 7% in southward view and 30% of buildings have no windows.
2. Openings of double-storey buildings, (doors) in all 13 buildings are located in eastward view and a building has a door in eastward view in addition to southward one and (windows) around 77% in eastward view and a building in southward view as well as northern side have a door and 15% of buildings have no windows.
3. In both single and double storey buildings, the length of window is 0.6 m, its height is 0.8 m and the ratio of window height to storey height is around 20% and the ratio of window area to storey area is 5%.
4. In both kinds of buildings mentioned, door width is around 1 meter with a height of 2.05 and the ratio of door height to storey height is around 65% and the ratio of door area to storey area is 10%.

Consequently, openings are located merely in eastward and westward views and about 6 of 26 buildings studied (around 23%) have no windows.

Protection of openings: all openers in eastward and westward parts are located in double-storey building category provided that eastward terraces with average width of 2.39 m and southward terraces with average width of 2.21 m are placed in single-storey buildings and eastward terraces with average width of 2.75m and southward terraces with average width of 1.72m are placed in double-storey ones (Table 3).

F. Building Envelope

Walls: outside walls of Lothian's buildings are wooden. Wall sections are 35 to 40 cm thick and their u-value is low (u=0.48) which acts as a good insulator. Wooden walls are coated with a plaster of straw and clay.

Because the instability of daily temperature is low, saving heat is not needed and buildings are made with minimum thermal capacity. Light building materials increases the influence of ventilation and draught which are necessities of the region. The color of appearances is mostly white because it absorbs less heat from the sun so it prevents inner space of the building to get so hot during summer.

Roofs: due to consistent rain during most times of year, the ease of leading the rain from building's outer surface to the ones under is very important. Because if water enters the materials, they are demolished very fast and this makes the building so damageable. So 4-slope and conical roofs are a right response for warding off rain water. Because inclined rains, from any side they fall on roof, can be transferred easily to inner surfaces. The amount of gradient of a roof covered with Kolush (rice stalk) is around 200%.

All kinds of houses are measured based on general form of building, main appearance and main form of building (Table 3). The houses are located in 16˚ north-west axis and in all kinds, northwest-southeast walls are longer than northeast-southwest ones (Fig. 12).

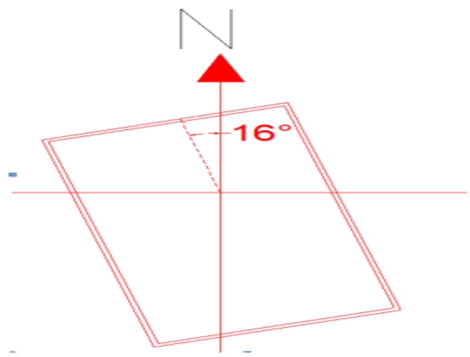


Fig. 12 Orientation on a 16 ° north – west axis

This kind of orientation creates this theory that based on Mahoney tables of the axis mentioned; the best axis is for providing maximum comfort which work well with sun, light, weather and temperature of inner space. One other suggestion made by Mahoney table is the preferable use of semi-condensed construction forms and materials with low thermal capacity in building crust and also constructing houses with big courtyards.

V. LAHIJAN: A SUSTAINABLE IRANIAN VERNACULAR SETTLEMENT

The fact that Lahijan has maintained its qualities for more than a hundred years suggests that the techniques of its construction and the building materials employed were well thought professional choices aiming at sustainability. Moreover, traditional builders did not only aim at achieving comfort without the need of any mechanical systems, but were also concerned about energy, material costs, as well as the impact of the buildings on the environment. This becomes obvious by their use of recyclable materials.

Therefore, the vernacular architecture of Lahijan can be defined as sustainable. The criteria that lead to the creation of such a sustainable vernacular settlement are: 1) holistic consideration of negative environmental impacts that arise in the construction of buildings and their infrastructures; 2) design recommendations, which minimize the adverse environmental effects in building; 3) use of materials with low maintenance and energy efficiency; 4) selection of building materials that provide thermal comfort; 5) use of renewable and natural resources; 6) reduction of energy consumption by maximizing passive thermal comfort; 7) concern for integral quality: economic, social and environmental performance; 8) improvement of environmental quality; and 9) provision for comfortable living spaces [ ].

VI. CONCLUSIONS

Vernacular constructions in all regions are products of combining the experience and performance during centuries and can be used as a durable source of knowledge. Using vernacular materials coordinated with environment and climate is a factor which makes architectural identity of a region distinct from the other. So these constructions are studied regarding climate and green (sustainable) architecture all over the world. Considering precious patterns and principles of vernacular architecture is helpful in many of today architecture-related issues like lack of energy, environmental pollution, etc.

When designing Shikili houses, in order to create a desirable ventilation and natural cooling, air circulation and moisture exit in the direction of dominant wind (east) are used, in a way that the air circulates inside the building also appropriate openings are prepared.

Turning the building toward appropriate winds (eastward) and against disturbing winds (southwest direction) also considering sun movement in sky results in optimal use of sun's light and thermal energy in different seasons and coolness in summer and heat in winter.

Utilization of materials existing in the region (in this special kind of houses, it is wood) is due to their suitable function, consistency with regional climate and flexibility against environmental factors, also availability of those materials and decreasing transportation costs (decrease in energy consumption).

Using plants suitable with regional climate and growing different ever-green trees and deciduous ones considering necessity of shadow or sun light in different seasons results in creating variety and color in space, adjusting environmental conditions inside the building and purifying the air of environment and region.

Applying attached elements like terraces beside windows is a method of controlling depth and amount of sun shine into the building during summer and winter based on residents' demand for sun energy. Besides, appropriate angle of sunshine during winter makes the possibility of a good permeation of sun light to the buildings.

Double-covering the roofs (inclined), lightens the roof and helps with receiving heat from sun by the roof and makes a kind of insulator by the air blocked between two crusts. Choosing appropriate materials creates a perfect insulator against climatic elements of the region.

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