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## RESEARCH ARTICLE

## Achieving energy-saving solutions by studying stepped villages of East Azarbaijan, Iran.

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**Abstract**

One of the most important issues in sustainable development is energy saving. Static methods of heating and cooling buildings are one of methods of saving fossil fuels. In discussing sustainable development and therefore sustainable architecture, the obvious fact is that every building must interact with its surrounding natural environment. The controversial and significant aspect of this fact is manner of interacting and type of considered measures. In this study, stepped villages of East Azarbaijan, Iran were studied and Passive solutions in heating and cooling buildings were analyzed. Finally, data obtained in the two tables, which show the passive cooling and heating procedure in regional villages are presented. In this article, a survey – analytical methodology is used. Finally, the overall result was that renewable energies such as solar and wind were used as methods of creating thermal comfort in villages of the studied area and minimal use of nonrenewable energies has been made. Moreover, the south orientation of villages plays an important role in benefiting from the sunlight. Also, villages are located on a sloped ground, as a result of which parts of buildings are dug into the ground and the thermal mass of the earth is utilized as a source of comfort for residents. At last, the method obtained from the vernacular architecture can be used as a model in today modern architecture that maximizes the use of fossil fuels.

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**Introduction:-**

Climate is one of the fundamental and decisive issues in discussing of sustainable development. Because the issue of the sustainable development deals with saving energy consumption, especially fossil and nonrenewable energies; therefore, climatic design of buildings and structure of cities will play a significant and decisive role in reducing the fuel consumption and thus preserve it for future generations. By studying local buildings in every climate, it will be clear that all local buildings, are entirely designed and built based on climatic principles in order to make maximum use of natural energies and to cope with annoying heat and cold. This is fully consistent with each region's culture and is defined based on the vernacular architecture (Qobadian, 2006, 42).

The advent of technology and possibility to use fossil energies and mechanical devices, almost two centuries has created disruptions in the climatic and local design of buildings, particularly cities. Therefore, the issue of excessive use of fossil energy resources on the one hand and the environmental pollution resulting from its use, and on the other hand, has become a serious and threatening issue. In discussing the sustainable development, renewed attention to climatic design and return to the vernacular architecture and urban development is proposed. Moreover, architecture and urban development practitioners and experts are invited to seriously address this issue (Shahriyar Shaghaghi, Majid Mofidi, 87). Passive systems are used to provide thermal comfort in a building. Passive systems have been used in very old times, always they have been included in building designs. Issues of fuel supply, and environment pollution have doubled the importance of passive systems both for cooling and heating of the buildings, they are essential elements of building architecture. Elements of passive systems are fully related to primary decisions of designing architecture, secondly, they are effective elements of building formation and organization. (Leckner, 2006)

In this article, different passive methods for heating and cooling buildings in stepped villages in northwest of Iran have been investigated because these villages were formed gradually and in harmony with the environment. Also, best solutions were adopted to avoid environmental degradations because in these strategies, the use of nonrenewable resources is minimized.

### **Research methodology:-**

The purpose of the present research is to achieve passive heating and cooling methods in stepped villages in the northwestern part of Iran. The reason for the selection of stepped villages is that almost all villages are located on a hillside due to climatic and environmental reasons. In this article, two research methods are selected and are used in the research process. Initially, the survey method is used through field visits to facilities and bringing case studies from different villages in the region. In addition to field studies, information on villages has also been obtained from different studies and articles. Finally, data were classified and were presented in tables using analysis and comparison methods.

### **Sustainable architecture:-**

Sustainable architecture challenge is related with finding a comprehensive solution for environmental consideration, meanwhile it is to achieve life quality and cultural; socioeconomic and comfort values. (WGSC,2004) we may search on objectives of sustainable architecture in relation to environment and energy: sensitive buildings to vernacular needs must be created; energy consumption must be reduced to the minimum level; indeed we must necessarily consider vernacular sociocultural content for implementation of environmental technology. Sustainability needs a continues progressive effort. It is impossible to improve and modify constructed environment without peoples' participation. Sustainability requires compatible rules and regulations; consequently, it needs participation of communities through effective management of resources by focusing on equity. (Munier, 2005,5) Concept of sustainable development is the result of increased awareness of global connections; increasing environmental problems, socioeconomic issues; poverty; inequality; and concerns about a healthy future for mankind. Sustainable development links socioeconomic and environmental issues strongly. (Hopwood et al,2005:38-39)

Sustainable development emphasizes on environmental issues that is one of the three important domains. The task of architects is very serious and sensitive because they are up to 75% responsible for climate change either directly or indirectly.(Rogers,2005) Therefore, the architects must encroach the environment very cautiously. sustainable architecture is proceeding for decades; and the architects have developed and proposed many solutions for crises and problems of sustainable architecture. ( Gorji, 2010,92) thus, it is necessary to study old sustainable residential complexes.

### **Methods of creating thermal comfort:-**

Inside environmental condition of building must be even for physical and mental comfort of residents. Namely, thermal comfort (heating and cooling) and lighting require energy consumption. Extensive warm climate of Iran requires space cooling and it is the most important objective of the architects. A glance on old architecture in Iran reveals indicator elements in architecture structure of the buildings mainly used to satisfy thermal needs. They are main structure and configuration of the building. Although used elements in traditional architecture for cooling are not implemented in contemporary architecture; whereas principles of thermal physics are the same as those in the designing process of current passive system, sometimes , structure of the traditional elements is the same as that of current systems .(Vakilinejad et al,2013) Heating three-step approach includes: 1. heat retention, 2 passive solar heating 3. mechanical heating. The first step is to minimize heat dissipation through building's wall through insulation, orientation and appropriate surface-to-volume ratios. The second stage consists of collecting solar energy using passive methods. In the third stage, only a small amount of fossil energy is required for heating, which is not happen in Stages 1 and 2. (Leckner,2006) cooling requirements of buildings are best estimated by implementing a three stage design approach including: 1. Avoiding heat, 2. Passive cooling

Mechanical cooling.Passive solar systems use renewable natural resources of energy for heating, cooling and lighting and physical comfort in the building, only a small amount of mechanical devices are used for energy transfer. Designing process of these systems is directly dependent to the decisions of architect for conformability of other elements of architecture design.

### Climatic characteristics of study area:-

In this article, stepped villages located in the northwestern region of East Azarbaijan, Iran are studied. Climatic characteristics of the study area are as follows.

- Severe cold in winter, temperate weather in summer
- Heavy snowfall in the north and northwest parts of the country
- low humidity
- large air difference between day and night, which leads to large temperature difference between day and night and air temperature is sharply dropped during night. In this climate, summers are mild and the main problem for residents is extreme cold weather and heavy snowfall.



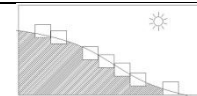
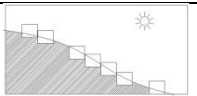
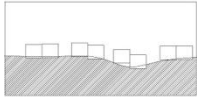
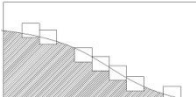
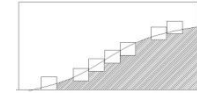
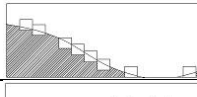
### Effect of climate on characteristics of village texture:-

Due to cold weather of the area, the texture of stepped villages in north-west of Iran is quite compact in order to have the least contact with the surroundings. In some of these villages, two-story buildings and in some villages one-story buildings or a combination of both are seen. Buildings have shared walls with neighbors to prevent cold penetration, resulting in minimum contact with their surroundings.

### Effect of climatic factors on orientation of buildings:-

Iran, which is located in the northern half of the planet, the east – west orientation is best direction for building. This means that length and width of buildings must be located in east – west and north-south directions, respectively, because the south wall absorbs most of the energy in winter and this wall can be protected using canopies in summer. East-west walls, which absorb enormous amounts of energy in the summer, should have a lower surface if possible. It is also better to build western walls under the shade of trees or buildings. (Qobadian, 7, 2006) In stepped villages of north-west of Iran, as investigated in Table 1, all villages have shared north-south slope, which allows most buildings to use the south light. Villages with secondary west –east slope, besides the south light, benefit from the east light. Also, villages with secondary east-west slope will benefit from the west light and since the west light is not suitable, the west light is prevented from entering sunlight in the summer with the construction of deep canopy.

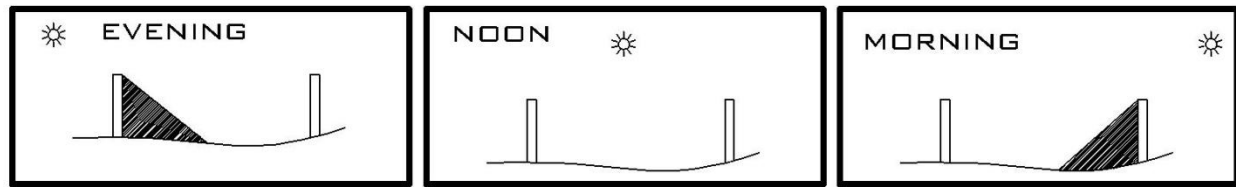
**Table 1:-** Types of stepped villages of East Azarbaijan in terms of slope direction.

	Type1(The slope in one direction)	Type2	Type3	Type4
steep direction	North to south	North to South, West to East	North to South, East to West	Combine type 2 and 3
the surfaces toward the sun	East, West, South	South and East	South and West	South, West or South and East
north-south section from the village				
East-west section from the village				

### Effect of climatic and environmental factors on streets direction in villages:-

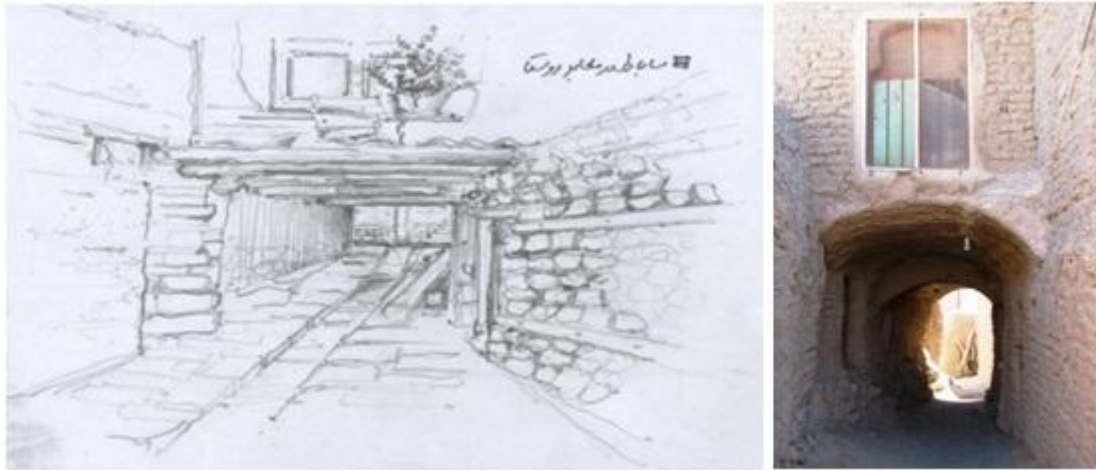
The direction of main streets within the village is proportional to the main slope i.e. north to south and alternate routes have often east-west direction.

Since one of the problems in stepped villages of the north west part of Iran is heavy snow and road closure, selecting north-south direction is an appropriate solution to melt snow by the sun so that in the morning, evening and at noon, the western, eastern parts of main routes and the entire width of the main route are exposed to the sunlight, respectively, which helps to melt snow (**Qyabegloo**).



**Figure 1:-** North-south direction of main routes in villages allows sunlight to reach all parts of the routes and help to melt snow in winter.

Alternate routes that often have east-west direction are usually in the shade most of the day, for this reason, snow and mud accumulate in them. This problem is often resolved by constructing canopies or roofs, which are called **Sabat** to prevent snow from covering the ground. In some villages, the second floor of buildings covers the side alleys (Figure 2)



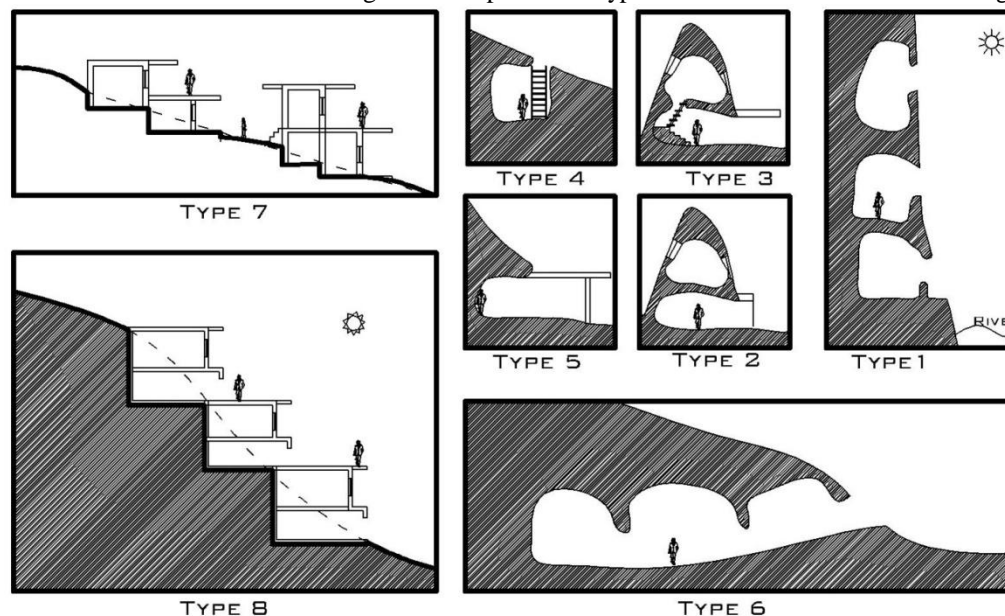
**Figure 2:-** Construction of roofed routes along alternate routes in the village.

#### **Manner of contacting with the Earth in stepped rocky villages of East Azarbaijan:-**

Earth due to its large mass can create time lag advantage. At about 6 meters of depth, the average effect of the summer heat and winter cold is equal to a constant temperature in the steady state, which is roughly equal to average annual temperature in that climate. Thus, Earth is cooler in summer and warmer in winter than its surrounding. (Lekner, 2006) The main philosophy of the formation of stepped villages, in addition to avoid the risk of flooding and attacks of different tribes and animals, is because of the Earth's potential for cooling in summer and heating in winter. In the northwestern villages of Iran, maximum use of lands has been made. Figure 3 shows different methods of land use in residential areas. Type 1 shows a cross sectional profile of a natural rock, into which houses have been dug. These types of residential complexes can be seen in Jaraghil villages of Azarshahr suburbs. It is possible to commute between floors using vertical corridors constructed within rocks. The residents can use the south light because of the south orientation of this rock. Types 2 and 3 show houses that are constructed in icicle-shaped rocks. Type 2 in Figure 3 shows Kandovan villages. Animals are kept in the bottom floor and families live in upper floors and stairs in upstairs are carved on the exterior part of rocks. Type 3 in Figure 3 shows entrance of the upstairs from inside the building i.e. the downstairs. This profile relates to **Germi** village located in the territory of Turkey. In Figure 3, Type 4 shows buildings, which are completely dug into mountains and the entrance is located on the rooftop. These spaces are used for grain storage and are seen in most of stepped villages. Type 5 shows buildings that are a combination of rock architecture and handmade architecture, an example of which is a stone mosque in **Jaraghil** Village. In Figure 3, Type 6 shows examples of buildings that are dug into the ground and only the entrance door is seen from the outside. Examples of such type of architecture can be found in a village called **Soor** in Bonab County. In this type of architecture, rooms are interlinked and to reach back rooms, first we should pass through front rooms. Types 7 and 8 of Figure 3 show examples of an evolved architecture, which is a mixture of ground and man-made architectures. In these kinds of stepped villages, roofs of lower houses are used as yards of upper houses. In villages with gentle slope (Type 7, Figure 3), in addition to the roof of a neighbor, the central yard, as outdoor space of houses, plays a major role in relationships inside the home. Tootakhaneh Village in Bonab



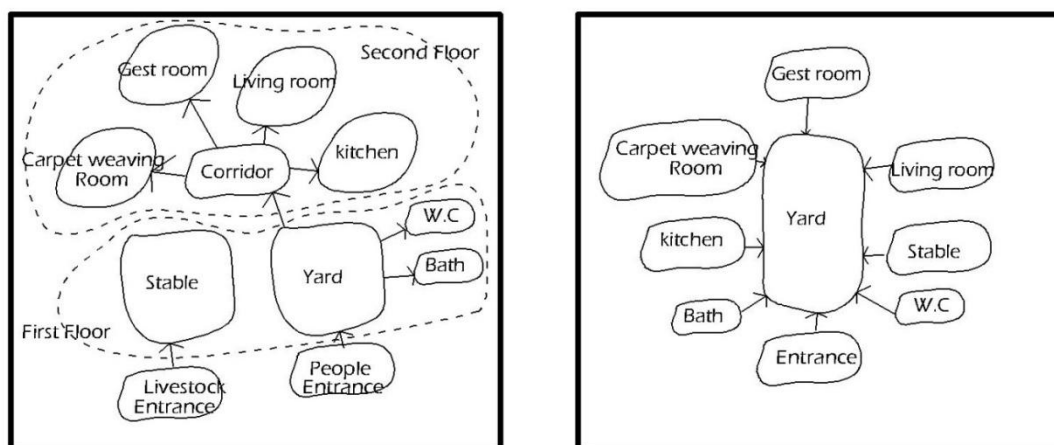
county is an example of this type of architecture. In villages with steep slope (Type 8), the ground floor is used as a barn and service space, living spaces are on the second floor and the central yard, even if there any, plays a less significant role in relations inside the building. An example of this type of architecture is Oshtobin Village.



**Figure 3:-** Different types of stepped and rocky habitats' contact with Earth in villages of East Azerbaijan

#### Characteristics of buildings in stepped village located in East Azarbayjan of Iran:-

Due to being situated on a sloped land, stepped villages' plans are different from villages situated on a flat ground. In stepped villages, roofs of lower houses are considered as the upper houses' yard. In many stepped villages, the central yard plays a less significant role in organizing spaces compared with villages located on a flat ground, because the ground floor is dedicated to the barn, the upstairs are used as living spaces and yard solely plays role of an entrance to the top floor. Oshtobin and Kandovan are examples of such villages. In some villages, which have less steep, yard plays a more significant role and all spaces are connected to the yard. Due being situated on a sloped land, these yards have low width and high length. In some of these villages, families enter the barn from the yard. In these types of villages, entrances of barns and living spaces of humans are not still separated. Tootakhaneh is an example of such villages. But in some villages, barns' entrances are separated from living space of humans. Oshtobin Village is an example of such villages. Figure 4 shows spatial relationships diagram in two stepped villages of Oshtobin and Tootakhaneh. In both cases, buildings are situated in a way to make maximum use of sunlight.



**Figure 4:-** A. Diagram of spatial relationships in Oshtobin Village, B. Diagram of spatial relationships in Tootakhaneh Village

### Effect of climatic factors on buildings characteristics of the villages in the region:-

- In stepped villages, roofs of houses are considered as an open space for the neighbor's house. In some villages buildings have a central yard inside the building as well.
- In stepped villages, buildings are constructed in a way to make the maximum use of land. ( Figure 3)
- Rooms' height is low for easy heating in winter.
- Roofs of Buildings are flat.
- To retain heat in buildings, windows dimensions are relatively small.
- To direct south sun light into the building in winter, south porches have a shallow depth in order to just prevent the summer sunlight from entering into houses.

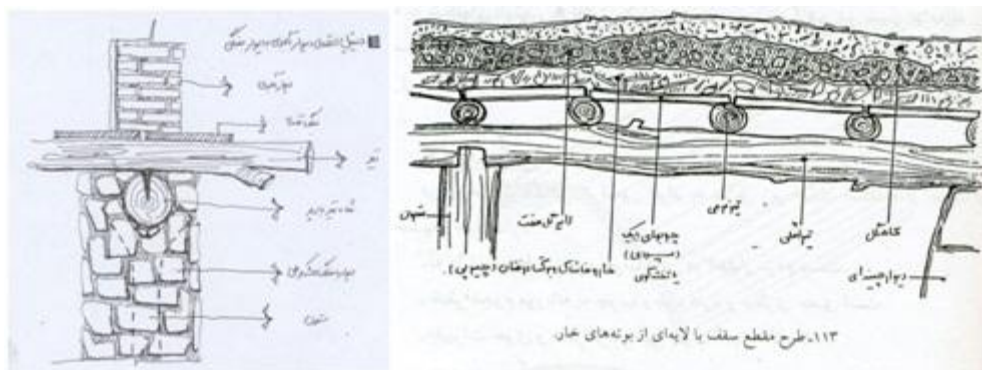
### Role of construction materials in heating and cooling of buildings:-

In East Azarbayjan villages of Iran surrounding materials were used to build houses.

Foundations and walls are constructed using stone, or brick or a combination of both. Stone and brick of a relatively large width, have a high thermal mass.

Materials with high thermal mass, when they are exposed to high temperatures can hold more heat compared with other materials (Gregory et al, 2008). They also release stored heat at lower speeds when the heat source is removed. During winter days, materials with high thermal mass, store thermal energy obtained from the sunlight, which enters the interior space through openings and is confined and then when the sun is down in the evening, the heat source is removed and the need to heat in the interior space is intensified, they slowly release the heat into the house. This would reduce the building's heating load (Balaras,1996). In summer, the materials gradually absorb the thermal mass of the heat generated by the sun in indoor spaces and prevent sudden rise in temperature. When the materials are accumulated with heat, they begin to release heat stored in themselves. They release part of that heat back into the interior space (in case of appropriate time lag), the heat can be discharged by the pressure differences caused by lower temperature of the outside compared with inside temperature and consequently the air flow (caused by convection) is discharged, Moreover, in case of cloudy night sky, which acts similar to a black body the heat discharge can be accomplished more quickly (McMullan, 2007).

Roofs of East Azarbayjan villages in Iran are often flat and covered with timbers and thatch. Sub-timbers are nailed on main timbers with less than a meter from each other and planks are nailed on these sub-timbers. Planks are covered with lightweight materials such as brushwood and dried leaves and a row of firm clay and eventually plated thatch will cover them. These types of roofs due to material type and their pores are good thermal insulation against the cold winter and appropriate for the cold climate of the region. (Figure 5-B)



**Figure 5:-** A- Detail of process of connecting the roof to the wall in the village of oshtobin, East Azerbaijan, B – Details of thatched buildings' roof

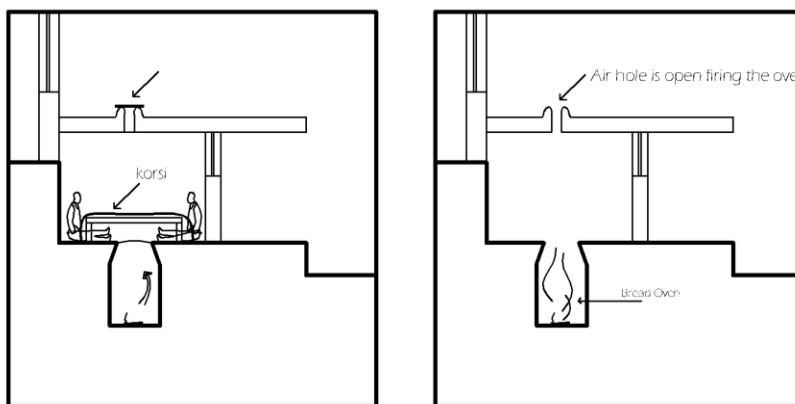
### Use of barn heat for home heating:-

Barns are located in two ways in stepped villages in Azerbaijan: Villages where animals live in the downstairs and human lives in upstairs and use the heat generated by animals' body to heating upstairs. In these cases, entrances for barns and living spaces are separated . In some villages, such as Tootakhaneh, although houses are built on a slope, they have a central yard and livestock entrance interfere with house entrance. In these villages, the living room is usually placed near barns on the ground floor, while it is dug into the mountain from other side in the mountains and receives the required heat from ground and barns.

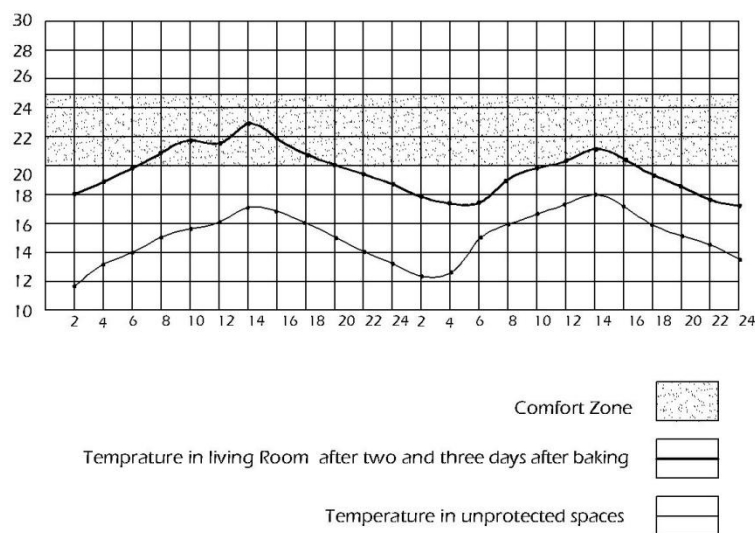
### Heating manner of the living room in rural areas using fossil fuels:-

In rural areas, Living room and guest room are parts of the house, in which fossil fuel is used for heating. In the past, firewood burner or Kerosene heater was usually used in the guest parts, because the room is not always used and, if necessary, was rapidly heated using heaters. Living room is part of the house, which is used by family members all year round. Korsi is a creative solution used in most villages for heating. Korsi is composed of a wooden table or stool with size of 1x1 meters of rectangular shape, which is about three inch long. A cloth with size of 4x4 or 7x7 meters covers the surface of korsi to prevent the heat generated by the heater from being wasted. People usually use a couple of cushions, pillows and backrest to sit and sleep around korsi. Therefore, low heat of brazier was used for heating in winter. In this method, very little fuel was used for heating. Another creative solution that was seen in some villages such as Tootakhaneh was the transfer of the winter tandoors to a corner of the living room. Since, they baked bread during 2 to 3 days of a week, in the past, tandoor's heat remained there for several days and was used to heat the inside of the house, in such way that after baking bread, then the tandoor oven was turn off and korsi was placed on it and it was covered with a thick quilt. The heat released from the tandoor produced warm air beneath korsi. Diagram 1 shows the above-mentioned temperature in two consecutive days in the living room and outside space in a house located in the village of Tootakhaneh.

As the above diagram shows, room temperature is somewhat in comfort range after two and three days after baking without the need to other heating appliances using this heating technique.



**Figure 6:-** Winter tandoor in the living room in Tootakhaneh Village.



**Diagram 1:-** Above-mentioned temperature in two consecutive days after bread baking in the living room and outside space in a house located in Tootakhane Village.

In the following table solutions for heating buildings in stepped villages are presented.

**Table 2:-** Passive heating process in stepped villages of East Azarbayjan

heat retention	passive solar heating	mechanical heating
Compact Texture, sinking buildings in the ground for the use of ground thermal mass, The use of small windows to prevent heat loss, proximity with neighbors to reduce the buildings relation with the environment	proper orientation of the villages to south to benefit from the sun , absorbing solar energy through walls and ceilings with high thermal mass during the day and transferring it with time lag into the building during night	the use of korsir, firewood burner or Kerosene heater for heating the living room and gest room

**Cooling manner of stepped villages:-**

Passive cooling is more dependent to climate than passive heating, thus, strategies of passive cooling are very different for hot and dry climates than hot and humid climate. There are five technics for passive cooling: 1.Cooling through ventilation 2.Cooling through radiation 3.Evaporative cooling 4.Ground-source cooling 5.Dehumidification. In some areas a combination of the mentioned techniques are used. (Leckner,2006)

Cooling through ventilation: air transfer is basis of passive cooling , increased evaporation power creates cooling. In passive cooling air movment is provided via wind or chimney effect ; combined systems use fan for airflow. Ventilation takes place when hot air is discharged and cool air is displaced , a combination of air transfer and evaporation create cooling. (Fuller. M) cooling through ventilation is dependent on wind force, ventilation due to chimney effect, chimney cap and method of double-skin roof. In a stepped village, wind flows from the bottom of the valley to the top of it. Wind along with the evaporation of river water act as a factor contributing to the cooling of buildings and during cold nights, wind flows from the top to the bottom of the valley and back to windows and does not involve buildings.

Evaporative cooling: latent heat of water droplets on wet surfaces exchange heat and create evaporative cooling. Evaporation of wet surfaces is used to cool inside area of the building directly or indirectly. Evaporative cooling is effective in hot and dry areas where humidity is lower than 70% , where evaporation capacity is high (Fuller. M, 2003) Presence of river in the valley along with the wind that blows over it to reach the village is an important factor that acts as an evaporative cooler in stepped villages.

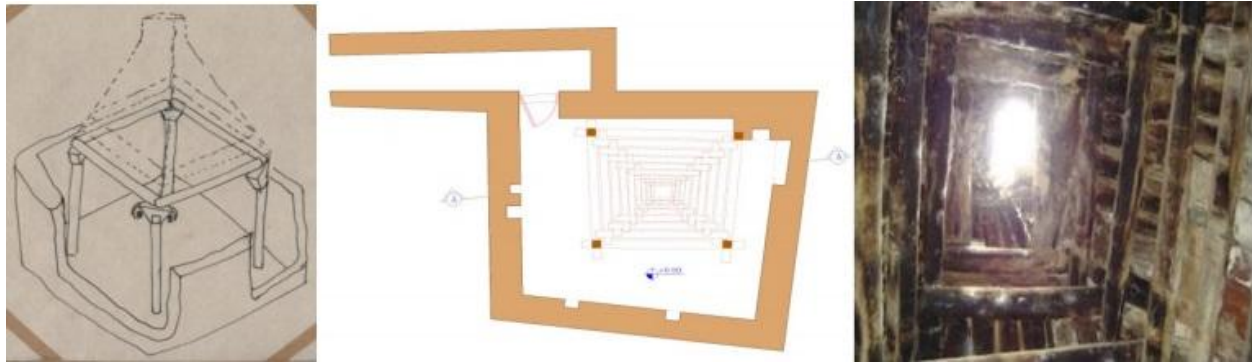
Radiation cooling: night radiation from walls and dense construction materials is dependent to the clear sky to crate radiation cooling . it is heat transfer from hotter surface to the surrounding cooling surfaces. Where the earth is dryer, more heat is radiated to the external surfaces. (Vakili et al,2013) Radiant cooling occurs through the buildings' roofs of stepped villages of East Azerbaijan,.

Ground source cooling due to the mass effect: earth is an unlimited heating source with high thermal storage capacity , it is used for seasonal heat storage. Soil temperature is almost constant in 6 meters depth , it is 2 or 3 degrees more than that of mean annual temperature (Leckner,2006) increased depth reduces annual fluctuations of soil temperature and it creates time delay. Thus, constant earth temperatures are used to cool a building. Direct and indirect contact with soil is used for cooling. Walls of building are fully buried under soil and thermal air channels cool the building indirectly (Fuller.M,2003). Thermal materials of the walls are a sample of daily cooling cycle through mass effect. Due to the maximum contact with the ground and the presence of thick brick walls in the stepped villages of East Azerbaijan, cooling effect if the Earth's mass by reaches its highest level.

**Preventing sunlight radiation to the building:-**

In many stepped villages, interior spaces are connected to the outside environment just through the skylight. Such spaces are very cool in summer; for example, in oshtobin Village, **Booneghi** is one of the special architecture elements of the village, which can be also called an unseen house since it was built in such a way that it had a hidden mode and other than the window constructed on the roof, there was no opening for lightening and ventilation (Fig. 7). Its height is roughly equivalent of two-storey buildings and four wooden columns, which usually have carved column heads, hold its wooden pyramidal roof.





**Figure 7:-** Booneghi, a space that has no access with the outside environment except through a small ceiling skylight (oshtobin Village )(Mohammadzade.R, 2013)

**Table 3:-** shows Passive cooling process in stepped villages of East Azarbayjan.

Avoiding heat	Passive cooling	Mechanical cooling
Compact Texture, Create canopies to the South and West to prevent the sun, The use of small windows to prevent sun light into the building, , proximity with neighbors to reduce the buildings relation with the environment, sinking buildings in the ground to avoid sunlight and heat	absorbing solar energy through walls and ceilings with high thermal mass during the day to Avoid overheating the building and transferring it with time lag into the building during night , cooling through ventilation by the use of daily wind that blows down the valley to the top, Evaporative cooling by the river water, Ground source cooling due to the mass effect , Radiation cooling during the night	Using fans

### Conclusion:-

In stepped villages of Azarbayjan in Iran, passive three-stage heating principles can be seen in heating buildings. The first stage relates to building heat preservation, with low surface to volume ratio, construction of small windows, maximum contact with the ground, and proper orientation of villages to benefit from the sun.

In the second stage, by building thick wall with high thermal mass, solar heat is stored in the building and is used during the night for heating the building. In the last stage, spaces were heated using korsi and minimum fossil fuel and finally firewood burners or Kerosene heaters were used for heating buildings.

Azerbaijan stepped villages in Iran have mild summers and comfortable conditions can be established in buildings using passive methods such as cooling through ventilation, evaporative cooling, radiant cooling, mass effect cooling, cooling by preventing solar radiation to building.

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