SUSTAINABLE SYSTEMS AND THERMAL COMFORT EVALUATION IN TRADITIONAL HOUSING

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ABSTRACT

Sustainable system strategies are an important characteristic of the traditional architecture defined by the local micro-climate. Gjirokastra is an important historic city and represents a successful example of vernacular architecture, with the usage of local ecologic materials, climate design and regional tradition design. The present paper explores the thermal comfort and sustainable system strategies in traditional housing in the city of Gjirokastra. The study analysis three housing typologies i) Zekate house ii) Kikino Hose and iii) Fico House. The three case studies are important examples of traditional architecture, as the material constructions are local, the climatic design strategies are used. Different strategies are explored in summer and winter period. In addition, the study creates a background knowledge about the vernacular dwellings in the city and the solar passive strategies used. The study aims to orientate the modern construction towards climate responsive design, following the strategies used in the existing vernacular dwellings.

KEYWORDS: Climate responsive design strategies, housing, Gjirokastra, traditional architecture

INTRODUCTION

Traditional housing reveals the combination of local climate conditions, locally available materials, simple construction techniques, living style, traditions and socioeconomic conditions of the region. (Halıcıoğlu 2012). It is an important example of adaptation of construction to the environment and to the place (Alba et al. 2013). The natural and human environmental adaptation is essential for preservation and traditional architecture used for solutions of adaptation to the new functional and technical standards. The traditional housing takes maximum advantage of the environment's possibilities with the optimal economy use (Yung, E. 2012). Building materials are available and taken near the construction site and defined by the natural and human characteristics of the zone, creating a regional type of architecture. Vernacular architecture varies widely with the world's vast spectrum of climate, terrain and culture (Zhai & Previtali, 2009) while representing good examples of optimal use of natural light and other renewable resources. Recent studies on vernacular housing have shown that bioclimatism is an integral part of vernacular architecture and an important parameter towards achieving sustainability of modern architecture (Dhar et al.2013). Several studies have revealed the good thermal performance of vernacular buildings in the Mediterranean climate context using both qualitative analysis and quantitative measurements for building performance, emphasizing the benefits of using local materials (Fernandes et al. 2014).

METHODOLOGY

Case Study Selection

The three houses chosen for the study are i) The Zekate house in Palorto quarter ii) Fico house located in Palorto, iii) Kikino which is in the Manalat quarter. The three case studies are important examples of traditional architecture, as the material constructions are local, the climatic design strategies are used (see Table 1). The dwellings are located in three different parts of the city in a distance from each other, which represents a specific house plan organization adapting to the site of the location (Figure 1). The Zekate is situated in Palorto quarter and being isolated from other buildings in a hilly landscape following the typography. Kikino is located in the Manalat quarter, in the suburban, with many trees around. Fico house is positioned in an urban area with entrance directly from the street. The Zekate and Fico house are

representatives of two-sided variant, with two rectangular blocks connected by a central block. The Kikino is a one-side variant, with two rectangular blocks connected angularly. The three case studies are declared monuments of the first category.

Table 1: General information of the case studies chosen

House type	Location	Year	Historic period	Architectural style	Variant	Monument category
Zekatet House	Palorto	1811-1812	Ali Pasha Rule (1811-1822)	Ottoman style	Two-sided	1st category
Kikino House	Manalat	1825	The end of Empire (1822-1912)	Ottoman style	One-side	1st category
Fico House	Palorto	1902	The end of Empire (1822-1912)	Barocco-rococo	Two-sided	1st category

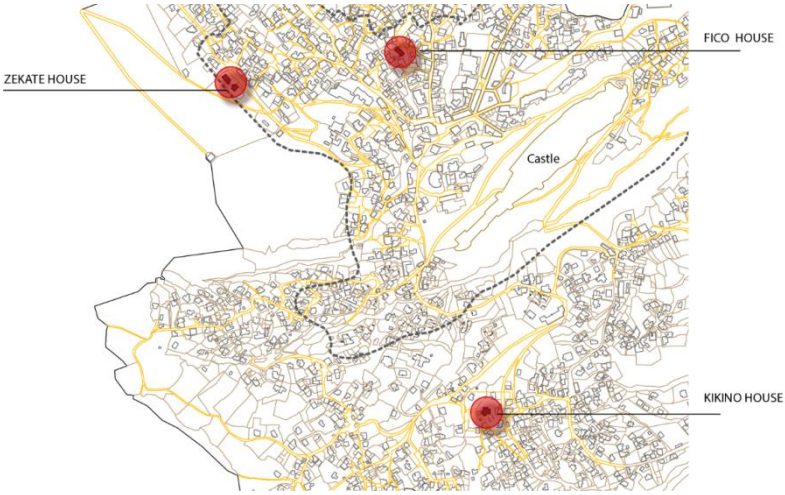

Figure 1: Map of the location of the case studies

Description of Selected Sites

Case Study A - Zekate House

The Zekate is a typical fortified tower-with a central block that connects two sided towers built at varying heights. The design of the house follows the steep gradient of the hills, being oriented towards north-east (Figure 2). The main entrance to the house is through the

main courtyard by stairs. The house is surrounded by three paved stone black courtyards which are connected by gates. The second courtyard is entered through a one –wing gate and encircles the main house. The third is found on the northern end of the central yard and continues into the house garden. The roads to the site were narrow, steep and winding. The yards of the Gjirokastra houses are surrounded by thick stone walls which define the property line.

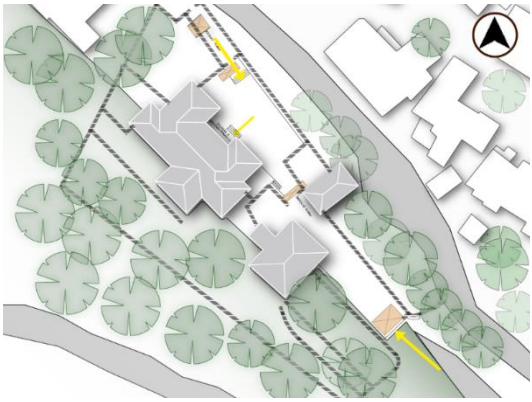

Figure 2: Landscape plan of Zekate House

The Zekate is a typical fortified tower-with a central block that connects two sided towers built at varying heights. The design of the house follows the steep gradient of the hills, being oriented towards north-east. The main entrance to the house is through the main courtyard by stairs (Figure 3). The house is surrounded by three paved stone black courtyards which are connected by gates.

The second courtyard is entered through a one –wing gate and encircles the main house. The third is found on the northern end of the central yard and continues into the house garden. The roads to the site were narrow, steep and winding. The yards of the Gjirokastra houses are surrounded by thick stone walls which define the property line (Figure 4).

The Zekate has a small footprint and is extended in verticality, following the hill typography. The house is composed of three floors. The central staircase goes upwards through the building. The first floor has two rooms that were used as living quarters for branches of the family, while the third floor has a grand reception room and two other smaller rooms.

Figure 3: View of the main façade of the Zekate house, the main entrance to the house and the cobblestone paved courtyard

Figure 4: The wooden entrance gate of Zekate

In the ground floor, the front door indicates to a lower hallway and in the right of the door is located the cistern head for drawing water. The cistern is fed by rainwater via a system of gutters around the roof. On the left is a large vaulted storeroom which would be used to store militing facilities (Figure 5). In the first Floor, the main space is the lower divan, or chamber for receiving guests. The other rooms are used mostly by the women for household and the cooking facilities. A door leads to a floor storage area for food, which is kept cool by the water cistern below (Figure 6). The second floor is composed of two main rooms leading off from the central divan. The winter rooms are positioned in the stone section of the tower, each containing a small toilette. These rooms used fireplaces for heating (Figure 7). The third floor includes a timber gallery occupied by the head of the family and his main guest to sit and enjoy. The walls are wooden lath covered with a special plaster compound produced by aged lime, goat hair, egg whites, and fine sand, mixed with straw. The mixture dries to a flexible, fabric-like skin (Figure 8). The main north-east façade has small openings in the ground and first floor and larger windows in the second floor. Because of the defensive character of the building and the typography design, the other facades are fully closed or with very small openings.

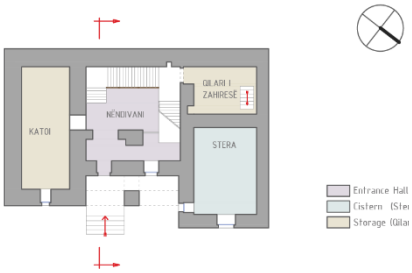

Figure 5: Ground Floor plan of the Zekate house

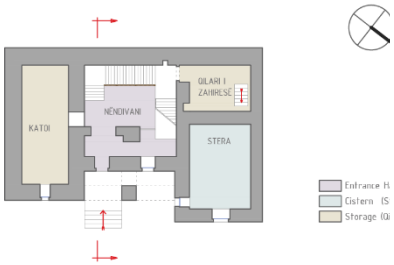

Figure 6: First Floor plan of the Zekate house

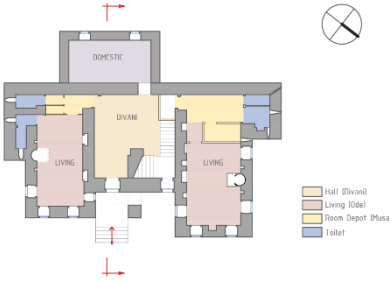

Figure 7: Second Floor plan of the Zekate house

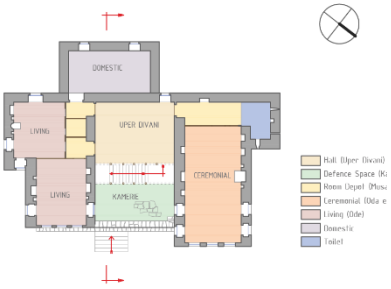

Figure 8: Third Floor plan of the Zekate house

Case Study B– Kikino House

Kikino House is located in the Manalat quarter, which is in the suburban areas. The location is a typography hill, with dense trees in the north, west and south. The building is oriented towards north-east and has two entrances, from which the main one is from east, towards the courtyard. The second entrance is from the back part following the typography of the site (Figure 9). Today the house is an example of the well-preserved structure, but its interior has had changes, from which the most important one is the change of the guest chamber.

The house is of the variant with one side. The composition is distinguished by the compactness, clarity and dynamic development of compositional units. (Figure 10) A characteristic of the Kikino house is a closed chamber in the main view. In the plan development, the two inhabited floors are expanded against the ground floor, adding to each of them a cooking environment.

Figure 9: Landscape plan of Kikino House

An unusual solution is the placement of the qilari zahirese in the wing block. The plan scheme floor of the two inhabited floors is the same. In each of them we find three living environments, and through an interconnecting passage it is passed between the two end areas, from the sofa and the cardak to the cooking facilities. Another important characteristic of this dwelling is the second intake of water from the stera, through a pit road that leads to the driveway of the end environments of the first floor. The chamber environment has a chimney. In the interior decoration, there are decorations with murals, with plant ornaments and everyday life. A special case is also the coverage of two doors that connect the cardak with the guest chamber (Figure 11).

In the Kikino house, the ground floor is used for storage with the qilari i zahirese, katoi and the stera. (Figure 12). The first floor is used for winter accommodation and the second upper floor is an opened cardak structure with the divani and living areas (Figure 13). The main north-east façade has small openings in the ground floor and the side facades have fewer apertures is used for winter accommodation and the second floor which is composed of timber structure (Figure 14).

Figure 10: The main façade of the Kikino house

Figure 11: The main entrance to the Kikino House and the main stone stair

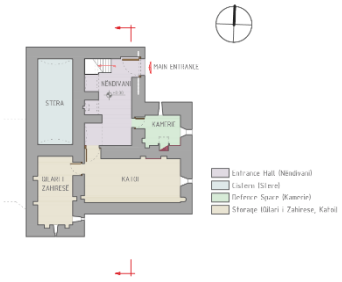

Figure 12: Ground floor plan of the Kikino house

Figure 13: First floor plan of the Kikino house

Figure 14: Second Floor plan of the Zekate house

Case Study C - Fico House

The Fico house is located in the Palorto quarter (Figure 15). The main entrance is through a courtyard directly street and the other from the typography in the back part (Figure 16). The Fico house is located in a denser urban area compared to other case studies and the entrance is directly from the street. The building has an orientation north-east and with trees mainly located in the east west part (Figure 17).

Figure 15: Landscape plan of Fico House

In the compositional plan, the building repeats the simple variant with two wings, adding a block in the right part. In the ground floor there are positioned the nendivani, katoi, stera dhe qilari zahirese (Figure 18). In the first floor there are positioned two living areas, the main central connecting part and a cooking area (Figure 19). The second floor repeats the same scheme (Figure 20). The main façade north-east has larger windows in the upper floors, which are used as summer living areas. The upper floor is a special volume called “musander”. The side facades have fewer openings.

Figure 16: Entrance of the Fico House

Figure 17: Tunnel connecting the building with the other part

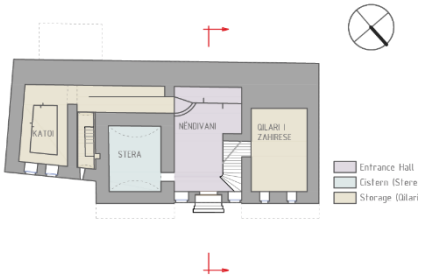

Figure 18: Ground floor plan of the Kikino house

Figure 19: First floor plan of Fico House

Figure 20: Second floor plan of Fico House

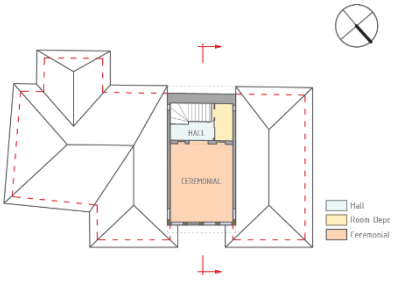

Figure 21: Third floor plan of Fico House

CONSTRUCTION MATERIALS AND TECHNIQUES

Case Study A - Zekate House

The façade is composed of stone in its original condition. The presence the chimney and its height were symbolic and represented the wealth of the household (Mezini, 2014). The House façade is uncoated and includes architectural elements such as: round arches, pillars, stairs, doors and windows in stone relief arches. Because of the rocky terrain the foundations are not very deep: the nest is built directly and on it the wall frame. The construction forms two distinct parts –a stone lower story topped by a wooden gallery of several rooms to house the extended family. Side facades have fewer openings than the main façade. The stone walls are 1 m thick at the base of the house and are bound with limestone mortar with an in-built band of wooden beams to give the house flexibility in case of earthquakes. The stone is local. The two tall columned arches, a structure called "kamerie", are aesthetic and from the construction aspect carry the weight of the upper rooms. The walls are made of limestone painted with a layer of mortar in the inside part. The stone on the façade is left in its original state. The staircase that winds upwards through the centre of the building is paved with grey slates outlined in a red paint that protects the soluble lime cement from being washed away by frequent cleaning. Wood, as an important element in construction and décor, can be seen in the window frames, serving both to protect and add an aesthetic element to the outlines of window fences. The floor is paved with red and black tile stone. The mezzanine floors are composed of wood tiles supported on wood trusses (Figure 22 and Figure 23).

The roof is composed of stone slates organized like a puzzle using only their weight to hold them. On the truss are put the battens in a distance 5-8 cm and on it the stone slates. The material used for the roofs is the timber wood. The "testekë" *(wood frame support sunders the roof connecting the roof and windows)* are structural elements. They reach sustainability of the wooden material, which is, in this case, the load bearer for the shelter and roof. The stone slates for the roof have been found in the neighbouring "Mali i Gjere hillside" and they are placed to create watertight roofs (Figure 24 and Figure 25). The construction detail section shows the layers of stone, wooden floors and roof composition is shown in (Figure 26).

Figure 22: Wood floor in the Zekate house

Figure 23: Ground floor in the Zekate house and main stair

Figure 24: Roof of the Zekate and the testeke

Figure 25: Roof construction element in Zekate House

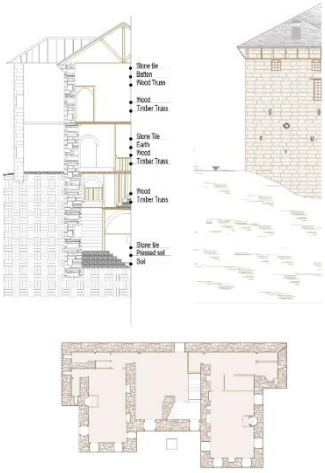

Figure 26: System detail of the Zekate House

Case Study B – Kikino House

An important architectural characteristic is the frame that runs through the two parts of the kamerie, as well as the top of the cardak frontal arcades. The house is covered by greenery on the walls which affects positively the indoor thermal comfort (Figure 27). The stone wall thickness varies from are 1 m thick at the base of the house and is diminished with 10 cm for each of the other two floors *(90 cm for the first floor and 80 cm for the second floor).* The walls are connected with limestone mortar with a band of wooden beams. The stone is local. The two tall columned arches, a structure called kamerie, are aesthetic and from the construction aspect carry the weight of the upper rooms. The walls are made of limestone painted with a layer of mortar in the inside part. The stone on the façade is left in its original state (Figure 28). The staircase that goes through the building is with stone structure paved in grey tiles. Different parts of the building have wooden floor such as the divani and the first floor. Also, other parts are stone tile floor pavement. As in other examples, the roof is made of trusses, the stone slates, standing on each other like a puzzle. Also, testeke are used in the divani area to support the roof (Figure 29 and Figure 30). They are a load bearer for the shelter and the roof. Wood is also used to frame the windows. In the upper floor, there are used Venetian coloured glass window in the living room. A system detail of the construction of the Kikino house is drawn in Figure 31.

Figure 27: The greenery used in the walls of the Kikino house

Figure 28: Facade of the Kikino House, the testeke and the unpainted stone facade

Figure 29: Roof of the Zekate and the testeke

Figure 30: Roof construction element in Zekate House

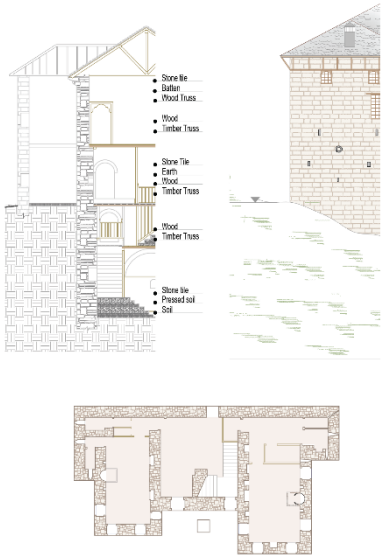

Figure 31: System detail of the Zekate House

Case Study C - Fico House

The interior and the external main façade illustrate the detachment from the old shapes. The main facade has two main volumes, two foreheads of the chambers of the second floor and the mansard. The main façade has wood decorations; the arched shapes of the erkers give to the house the characteristics of architecture with baroque influence (Figure 32). The stone wall thickness is 80 cm for the ground and first floor and 30 cm in the upper floor. The walls are stone

walls and are bounded with wooden trusses. The walls are made of limestone painted with mortar in the inside part and outer part. The floors are wooden and stone floors with wood trusses. Wood is also used to frame the windows. The roof is stone slate roof supported in wood trusses (Figure 33). The construction system detail has been drawn in (Figure 34).

Figure 32: Fico facade painted in mustarde colour in the outside: the upper windows are bigger

Figure 33: Fico facade painted in mustarde colour in the outside: the upper windows are bigger

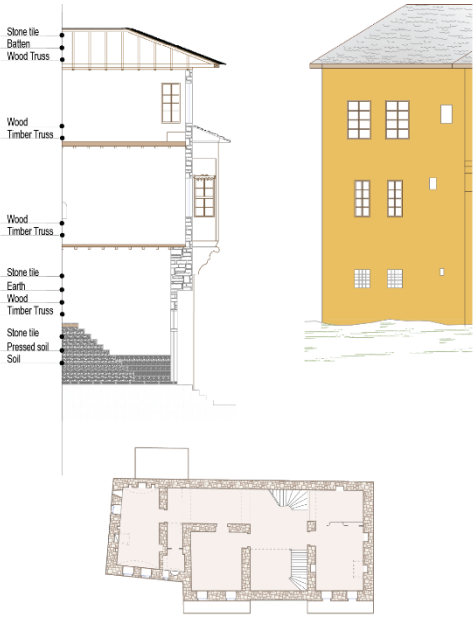

Figure 34: Fico system detail

A COMPARATIVE ANALYSIS

The main characteristic of these houses are balconies, verandas and courtyards. Also, they represent similarities in the construction aspect. They are characterized of thick walls with high thermal mass, wood and stone floor and puzzle structure roofs. Also, the foundation is not very deep in general because of the rocky foundation. The wall structure is heavy in the lower floors; stone composition with thickness decreasing and the upper stories are light wood opening structure or have more windows (Table 2). The three houses include different climate responsive strategies For summer season: i) The surrounding of the house with trees and design following the typography, ii) The deep roof eaves to provide shading, especially in the main façade, iii) Opened wood construction or large windows in the upper floor, which is used for summer accommodation. For winter season: i) Thick stone walls in the ground floor, for the thermal inertia and the wood structure in the upper floors. Also in the upper floors the thickness of the walls decreases, ii) The usage of natural materials such as wood, and stone (which is local and of a very good quality), iii) Orientation towards the sun and following typography design, iv) Small windows in the lower floors used for storage or winter accommodation. The north-east orientation of the main façade makes possible the penetration of a large amount of light. The usage of shading elements has contributed in the visual comfort of the house.

Table 2: Description of elements of the three selected houses

House type	**Foundation**	**Wall system**	**Roof structure**	**Floor**	**Openings**
Zekate House	Stone, not very deep, directly in the rock terrain	Stone wall,1 m to 70 cm thick, decreasing with 10 cm for each floor	Stone slates free standing supported on wood truss system Roof slope 25-30 Eaves 50 cm to 1,4 m	Stone in the lower floors and wood in the upper floors	The “cardak”, a lightweight opened wood structure

Kikino House	Stone, not very deep, directly in the rock terrain	Stone wall,1 m to 80 cm thick, decreasing with 10 cm for each floor	Stone slates free standing supported on wood truss system Roof slope 25-30 Eaves 1m	Stone in the lower floors and wood in the upper floors	The "divani", a lightweight opened wood structure
Fico House	Stone, not very deep, directly in the rock terrain. The back part is 170 cm to support the structure	80 cm to 25 cm in the third structure	Stone slates free standing supported on wood truss system Roof slope 25-30 Eaves 50 cm to 1.3 m	Stone in the lower floors and wood in the upper floors	Large windows in the upper part

INDOOR THERMAL COMFORT ANALYSIS

Thermal comfort is a condition of mind that expresses satisfaction with the thermal environment. The primary variables of thermal comfort are: i) Ambient temperature (air temperature), ii) Radiant temperature (the temperature of the surfaces around us), iii) Relative humidity *(measurement of the water air in an air -water mixture)*, iv) Air motion *(the rate at which air moves around and touches skin)*, 5) Metabolic rate *(amount of energy expended)* (Raish, 2009). The field survey was conducted in Gjirokastra via a questionnaire evaluating thermal comfort and to gather information about the perception of people about the environment of the dwelling. Interviews were developed with inhabitants of the city during the visit of the Bazaar of Gjirokastra. The questionnaires were developed for 30 traditional dwellings in the city. The two parts of the questionnaire include information about the temperature inside the house, humidity, air movement and ventilation and mechanism for ranking thermal comfort. The graph of the indoor temperature in summer shows that most of the people perceive the house as a cool environment in summer. Only a little percentage perceives it is uncomfortable and warm. The temperature in winter season is mainly perceived as warm by the inhabitants (Figure 35). Most of the people interviewed perceived the humidity level *(in winter and in summer)* positively (Figure 36).

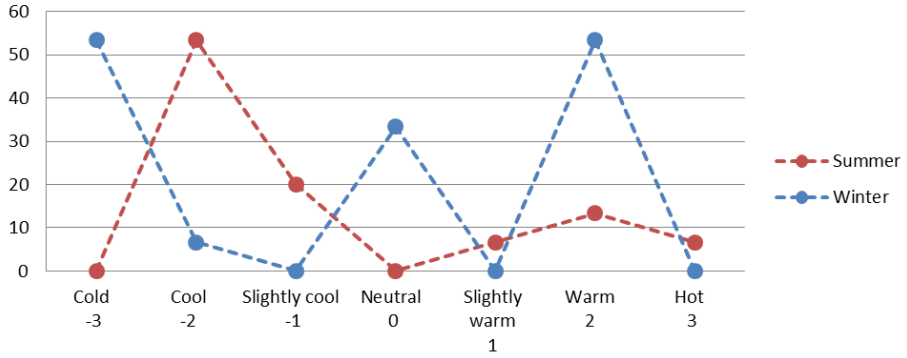

Figure 35: Subjective response on indoor temperature

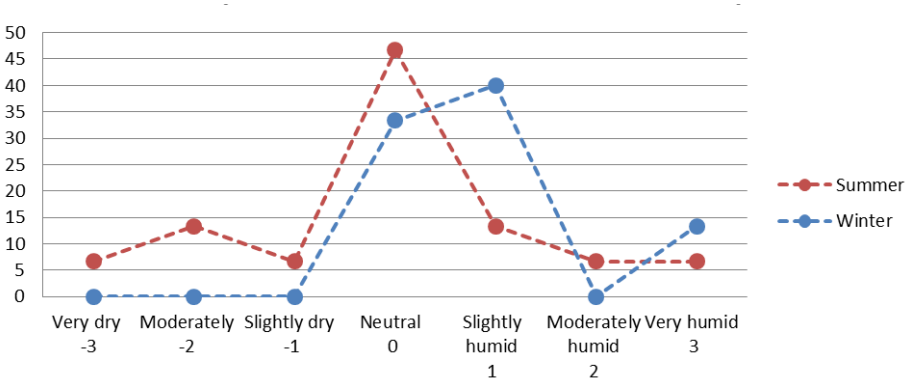

Figure 36: Subjective response on Humidity

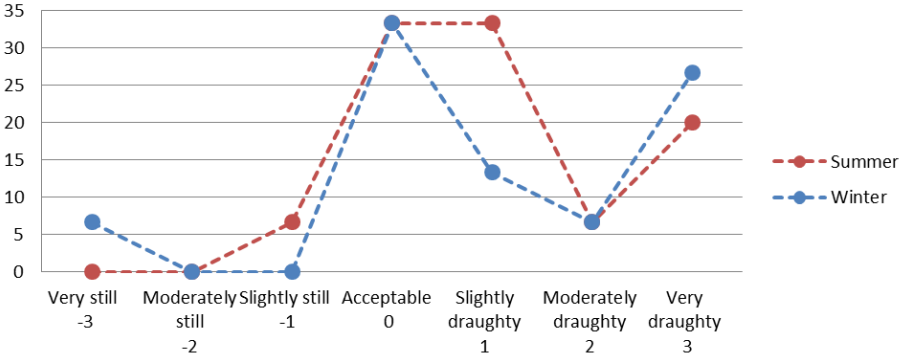

Figure 37: Subjective response on Air movement

An important variable which defines thermal comfort is the air motion and ventilation which can be perceived by visiting the traditional

houses in Gjirokastra, especially, the upper floors. The graph of the air movement in summer illustrates that during this season most of the people feel the air acceptable or slightly draughty, which means cool. The air movement and ventilation in winter is manly felt as acceptable (Figure 37).

As a general analysis of the thermal comfort of the houses in Gjirokastra by the questionnaire, it is valued that the general comfort in summer and winter is evaluated as comfortable. Most of the people interviewed expressed that the indoor system of the houses was very well ventilated and shaded during the summer season (Figure 38). Almost 80 % of the interviewed felt the very well ventilated inside spaces in summer so there is no need for use of mechanism in the summer season (Figure 39). In the winter the inhabitants felt a little the cold environment and the main mechanism used for warming was chimney which uses wood as an ecological material. Also, other mechanisms for warming were the air conditioner and air heater. The air conditioner is used in houses which have been restored and reused as hostel or hotels (Figure 40).

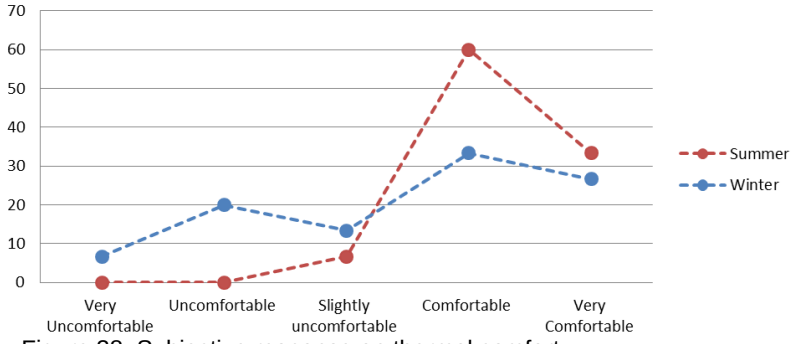

Figure 38: Subjective response on thermal comfort

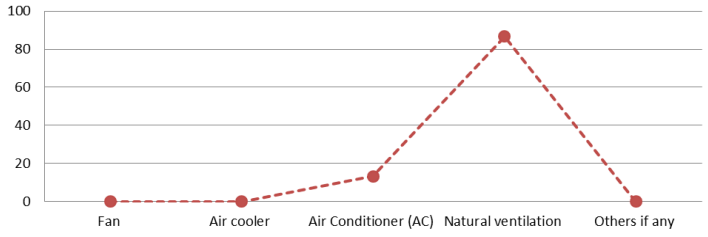

Figure 39: Mechanism used to overcome thermal discomfort in summer season

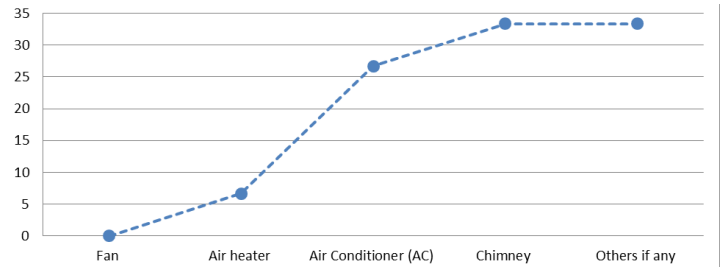

Figure 4. Mechanism used to overcome thermal discomfort in winter season

CONCLUSION

The main aim of the present research is to make an exploration of the passive solar strategies used in the vernacular dwellings of the city of Gjirokastra. The study has been conducted in three case studies: 1) Zekate house 2) Kikino Hose and 3) Fico House. The three buildings are monument of first category and are located in different landscapes. The main solar passive strategies for ventilation in summer have been studied in the level of the three main elements of building envelope: roof, walls and floors. A main characteristic of the Gjirokastra vernacular dwellings is the inter-seasonal design of spaces. The lower floors have thick stone walls, for high thermal mass and small openings. The upper floors are wood structure. The ground floors are used for storage the upper for summer and the below ones for winter accommodation. This division of circulation is followed by a specific design for heating and ventilation. High and large roof, deep eaves for shading mainly in the main façade and the light construction have contributed in the visual and thermal comfort of these buildings. The high thermal inertia walls, wood and stone floors and small openings in the ground provide a good warming in winter. The study aims to develop guidelines for climate responsive design and create background knowledge about the vernacular dwellings in the city.

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