Sixth International Conference on Construction in the 21st Century (CITC-VI)
"Construction Challenges in the New Decade"
July 5-7, 2011, Kuala Lumpur, Malaysia

Natural disasters mitigation measures in vernacular residential types of Guilan

Nastaran Mazhar Sarmadi
Lahijan, Guilan, Iran
Na.MazharSarmadi@mail.sbu.ac.ir

Seyedeh Hoda Rastgouy Haghi
Lahijan, Guilan, Iran
Hoda.Rastgou@gmail.com

Abstract

Guilan, as a northern province of Iran, has a humid and moderate climate due to its proximity to the Alborz mountain range, deep forests and the Caspian Sea which led to the formation of diverse vernacular building types. Each type has developed gradually over time to be in a harmony with its surroundings and climatic situation besides resisting probable natural disasters like flood, earthquake and heavy snowfall.

Identification of disaster mitigation measures in vernacular buildings according to their origins and study of their advantages and disadvantages for further use in new constructions can play an important role in decreasing the risk of disasters in modern buildings. As the field study indicates, vernacular buildings, despite being formed of a simple design, have intelligent capabilities to provide a better response to critical conditions in comparison with their modern counterparts.

Considering the diversity of vernacular rural types in Guilan, two types are selected for this survey located in different geographic and climatic zones and exposed to different natural disasters (flood and earthquake). These types are deeply studied from the viewpoint of their capabilities in confronting natural disasters. Afterwards the possibility of the promotion of these capabilities is assessed in order to be applied in modern construction.

Keywords

Natural disaster, Disaster mitigation, Vernacular buildings, Promotion, Capabilities

1. Introduction

Iran is an Asian country which is located in the Middle East. Its borders are with Azerbaijan, Armenia, Turkmenistan, Pakistan, Afghanistan, Turkey and Iraq. It is limited by the Caspian Sea in the north and Persian Gulf and Oman Sea in the south. Iran is the 18th largest country in the world with an area of 1,648,195 km² and a population of over 70 million.

Iran is a seismic country which has experienced many strong earthquakes in its long history. The probability of different disasters in this country (i.e. earthquake, heavy rainfall and snow, flood etc) indicates the importance of investigation of the capabilities of vernacular types against such disasters to be identified, promoted and applied for further construction projects.

Iran is divided into thirty provinces. Guilan is a northern province of Iran with an area of 14711 km² and is situated between the Caspian Sea in the north and Alborz Mountain range in the south. It is a province with high humidity and mild weather and its temperatures rarely fall below freezing. The most important issue about its temperature is the little fluctuation during 24 hours. Heavy rainfall in all seasons of the year made it the most verdant region of the country with dense forests. (Figure 1)

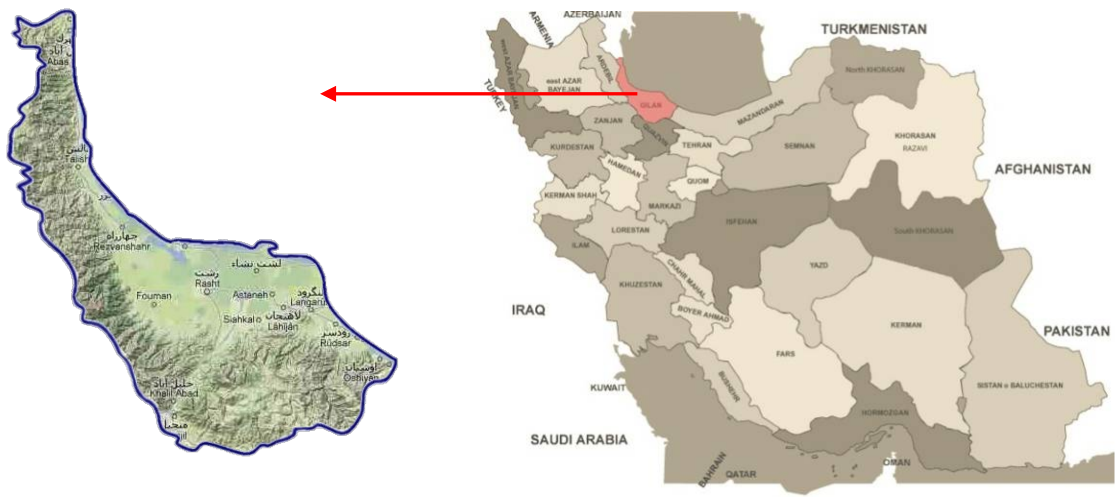


Figure 1: Location of the study area

The rural architecture of Guilan has faced many disasters (mostly earthquakes and floods) during past centuries which have resulted in the gradual development and adaptation of dwellings to their natural environment. Local architecture of Guilan exploited indigenous resources to form a sustainable building in an informative way. A thorough observation of different rural residential types in Guilan can be effective for utilizing this local knowledge in mitigating the effects of future natural disasters.

From the existing rural types in Guilan, two are selected for this study named “Shakili” houses and “Zigali” houses. The major reason for this selection is their outstanding architectural and structural characteristics and reasonable function against different disasters (flood and earthquake). The study of constructing materials and methods of these types beside their appearances and spatial organizations, clarifies their capabilities to resist disasters which are based on local knowledge and wisely utilized by the natives.

2. “Shakili” house

2.1. Introduction of the Shakili house

This type of rural residential architecture is situated in an area that is covered with vast pastures. Low levels of altitude, high levels of underground water in this region and the proximity to the Caspian Sea led to a specific mild and humid climate. Climatic conditions as well as immense open and flat grounds resulted in open pattern villages with distant houses.

Shakili houses have a cubic shape which usually consists of two stories. This type consists of three parts including an open balcony, semi-closed rooms and a steep slanted roof. The major façade of the house is oriented to the south-east to prevent from inadequate winter winds from the north-east and south-west. As it is known this direction is the best for absorbing solar heat in winter time. In most observed houses north and west directions have limited openings or are covered with sloped roofs. The roof is usually extended

to the ground in these directions to prevent the penetration of water into the building during heavy rainfalls.
Different types of spatial organizations are observed due to the livelihood and wealth of their residents From one storey to two stories and from one-room houses to four-room ones regarding the number of family members and their needs. The simplicity of the spatial organizations, with the ratio of 3:2 between the sides, in most cases lead to a modular plan with multi-functional spaces.

Shakili houses are built from natural and herbaceous materials like wood, plant and mud from the foundation to the roof. The most important issue is that all of the construction materials are prepared from the neighboring areas which could exceed the construction rate consequently.

Figure 2: Samples of the Shakili house (Form and Plan)

2.2 Construction method

Shakili houses are constructed on a platform and have high foundation in an attempt to avoid water penetration and providing air circulation to repel humidity. For building a platform the earth should be dug up to the depth of 1.5m and filled with a mixture of ash, coal and sand in layers which are rammed one after another to become completely compacted and makes an isolated bed for the building. The wood foundation consists of four layers of logs that are laid on each other in perpendicular directions and with no connection. Lower logs are usually selected from hardwoods which show better durability against humidity and upper levels are usually made from kinds of local trees that have acceptable tolerance against heavy loads. The distances between separate foundations are usually 1.5m. (Figure 3-a)

The walls of a shakili house, named “Orojeni” in the local dialect, are constructed of four meters long logs of 20cm in diameter. At first, two logs are laid on the floor on parallel sides with the distance of at most 3.5m. Then two others are laid on them perpendicularly forming lap joints at corners; although, in some cases cross lap joints are used at corners to increase the solidity of connections. After arranging the logs, the next step is covering and filling the gaps between, with a straw-earth mixture. In this way woods are protected from vermin attack as well. (Figure 3-b)

In this region because of heavy rainfalls, a steep slanted roof (100-200%) is constructed to simply drain the rainwater. The roof’s structure is built of softwoods which are connected to each other with herbaceous ropes. After all, for the final covering of roof, bunches of a kind of local plant called “Galli” are used and fixed to the structure from down to the top with a proper overlap. (Figure 3-c)

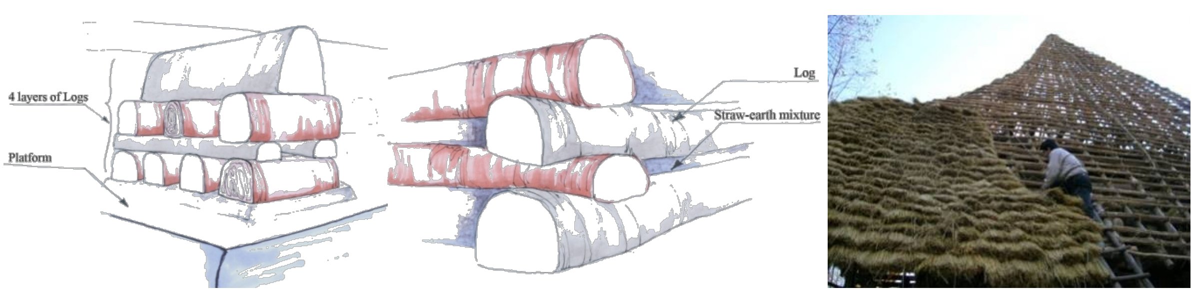


Figure 3: a) The shakili foundation, b) Orojeni wall, c) Roof

2.3 capabilities of the shakili house in confronting floods

Capabilities of the shakili houses can be observed in different ways from construction materials to construction methods. Observed disaster mitigation measures in shakili houses are:

a- Building an isolated platform which can resist water penetration due to the construction materials used to form it.
b- Constructing the platform up to 30cm above the surrounding grounds preventing floodwater from reaching the foundation.
c- Ramming the platform in layers of 15cm height to protect it from being washed out.
d- Formation of the ground storey at 1.5m height above the ground leads to the protection of the living spaces from floodwater in addition to the possibility for air circulation in order to repel water from wood foundation after floods.
e- Building the foundation from hardwood which has an acceptable capability to resist water.
f- High weight of the building type which can make it stable against floodwater.
g- Utilization of weighty woods which can be stable and unmoved against floodwater forces.
h- Using steep slanted roofs to exceed water drainage rates during heavy rainfalls.

2.4 Proposed promotion strategies

	Improvement strategy	Existed
1	Chemical treatment of wood foundation	
2	Stabilization of the surface of the platform	
3	Utilization of properly seasoned timber for constructing the foundation	
4	Surface treatment of wood elements such as painting with bitumen	
5	Utilization of reinforced concrete posts instead of wood foundation	

3. "Zigali" house

3.1 Introduction of the Zigali house

This rural residential type is situated in the central hillsides of Guilan province. The hillside area of Guilan is located between the plain area in the north and mountains in the south. In this region micro-climate is very similar to Guilan's general climate which has mild summers and winters. The villages of this area are laid on a slight slope and the whole area is covered with forests and green fields. The available houses of this region exploit the wood of indigenous trees which have affected the material usage and building techniques.

This building type has a simple cubic form with small extensions used for services or as a balcony. Its spatial organization is non-linear with a central hall which provides access to the surrounding rooms. It is usually built in two layers of rooms with a semi-open balcony at the front. This balcony is used for various purposes and provides an adequate transition from the open yard to the limited area of rooms. It is mostly constructed in two stories which are both allocated to living spaces.

The main facade of the building is usually facing southward to absorb the solar heat and appropriate wind. Its shorter sides generally face west and east except for other reasons such as land slope, the position of the ground proportionate to the road or river, etc. The openings are typically positioned in three perpendicular sides and their sizes are restricted by the wood structure of the building (the maximum possible width is up to the distance of columns).

The main construction material of the Zigali house is wood in different forms (e.g. timber, log, board etc.) for the various parts of the building from foundation to roof. In addition to wood, mud and straw-earth mixture are used to cover the walls, floor and ceiling. In most cases rubble is also used to support the wood foundations named “Pakooneh” of the building and fills the gaps between them. Herbaceous materials were utilized for covering roofs in the past which are extensively replaced with galvanized iron sheets fixed to the wood trusses by stainless steel nails.

Figure 4: Samples of the Zigali house (Form and Plan)

3.2 Construction method

First of all, the ground under the foundation is dug up to 100cm to make holes for the logs to be placed and fixed in. Distances between the holes are 100-150cm. The holes are covered by a layer of ash at the bottom with a flat stone laid on this layer to protect the wood foundation from being spoiled due to water penetration. The next step is to place the logs of 15cm diameter into the holes on the flat stones and fixing them by ramming and filling the holes with mud and rubble. These foundations have three main roles: 1) Preparation of a flat bed for the building to be laid on, 2) Separation of upper parts of the building from wetland and water transmission, 3) Transfer of the building load to the ground. (Figure 5-a)

The following step is to place hardwood, called “Nall” in local dialect, horizontally on the foundation. These timbers usually have tongue and groove connections or cross-lap joints at corners. (Figure 5-b) Timber columns are positioned straightly on the Nalls and are connected to them using stainless steel nails. Timbers of the ceiling are situated above columns and are connected to them by nails. Additional pieces of wood named “Ghochak” are used to extend the joint surface of the structural elements such as lintel beam and column. (Figure 5-c) Where the building consists of two stories, the whole operation is repeated to make an independent structure for the upper storey. Despite being part of a single building, each storey should act separately during a probable earthquake.

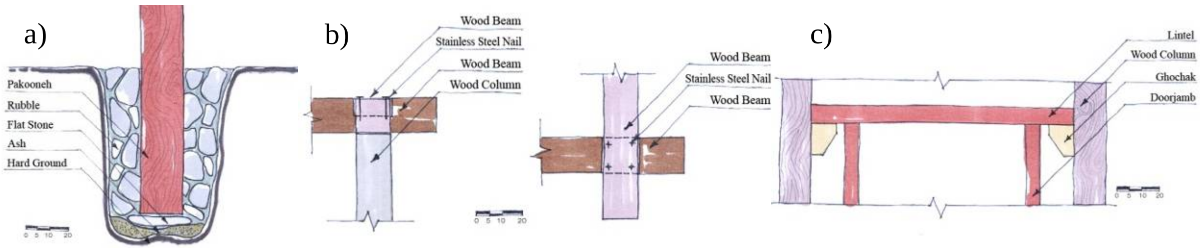


Figure 5: a) Wood foundation, b) Beam joints at corners, c) Joints between column and lintel beam.

After construction of the wood structure of this building type, it is time to fill the distances between the columns by nailing wood boards or thin stems of trees, called “Zigal” in the local dialect, diagonally at a distance of 10cm. Zigals are nailed to both interior and exterior sides of the structure in two layers in opposite directions. Then, the space between these layers is filled with straw-earth mixture balls that are pushed and pressed into the empty space. (Figure 6-a)

This housing type has a four sided sloped roof that is made of an Iranian wood truss and covered with galvanized iron sheets. The roof slope is around 20-30% which leads to various heights of trusses due to the different building lengths from one to another. Trusses are mostly built of logs 7-8cm in diameter as the roof ridges which are laid on timber beams at a distance of 60-80cm. (Figure 6-b)

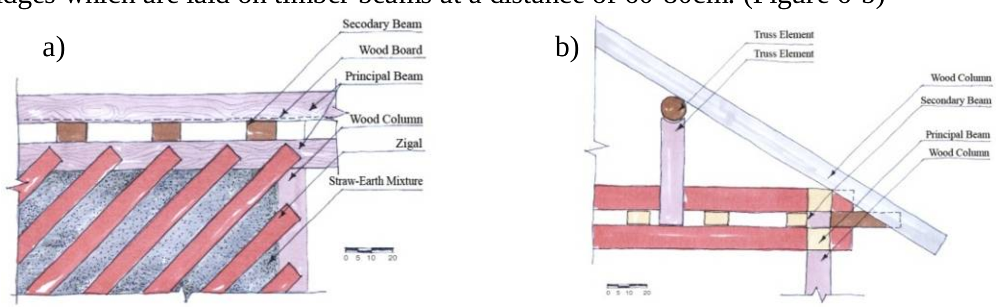


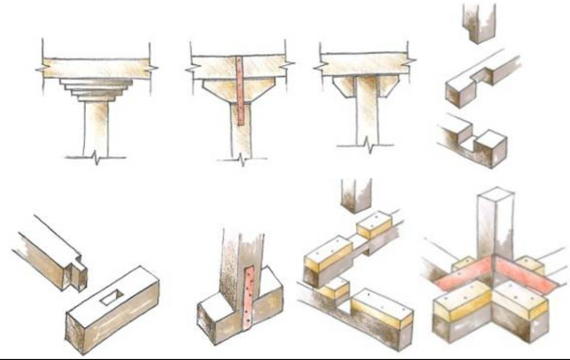
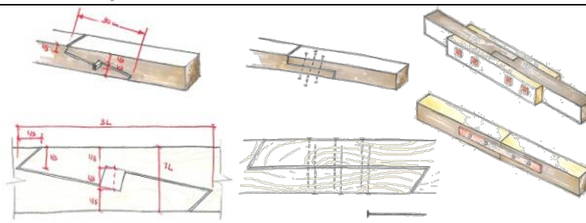
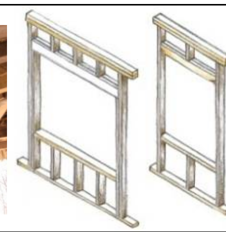
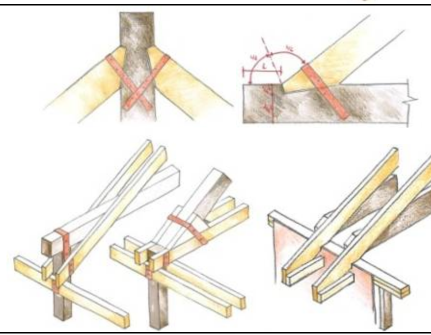
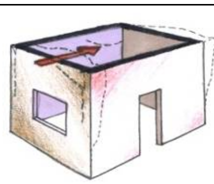
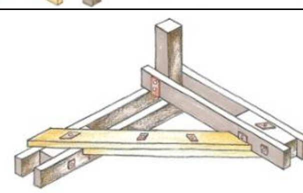
Figure 6: a) The zigali wall, b) Wood truss of the roof

3.3 capabilities of the zigali house in confronting earthquakes

There are different capabilities for resisting earthquakes in a zigali house which has been tested in the June 1990 earthquake in Guilan. Observed disaster mitigation measures in zigali houses are:

- a- Constructing a simple and symmetrical cubic shape without U, T or L shaped plans which can distribute building weight equally to prevent building torsion against lateral forces.
- b- Light weight of the building type.
- c- Stabilization of logs into the ground to an appropriate depth to make a strong foundation to properly transfer earthquake forces directly to the underlying ground.
- d- Utilization of adequate local hardwoods 15cm in diameter which are resistant to humidity and vermin attack by removing the bark of logs or painting their underground section with bitumen.
- e- Using appropriate tongue and groove or cross-lap joints between timber beams which results in better reaction of the building type during earthquakes.
- f- Convenient and regular distances between timber columns.
- g- Diagonal connection of zigals to timber columns and in opposite directions which can act as lateral bracing of walls.
- h- Using additional wood elements to steady the joints of beams and lintels to columns.
- i- Adequate cantilevers in the building (up to 80cm) which can increase building stability against upward vertical earthquake forces.
- j- Diagonal bracing of roof trusses to make it more stable against lateral forces.

3.4 Proposed promotion strategies

	Improvement strategy		Existed	proposed
1	Chemical treatment of wood			
2	Utilization of properly seasoned timber for constructing building structure			
3	Reinforcement of structure joints	Column to beam		
		Beams in long spans		
		Lintel beams to columns		 
		Roof trusses		
4	Stabilization of corners			
5	Surface treatment of wood elements such as painting with bitumen			

4. Conclusion

The rural population of Iran is around 35 percent of the whole population and Guilan has the most rural population with an average of 45%, therefore it is important to assess the reaction of vernacular residential buildings against natural disasters and their capabilities to resist them. Diversification of the climate of Guilan and geographic characteristics leads to the formation of various types of vernacular architecture. Two types of rural residential buildings were selected for this study which are: 1) The Shakili house (situated in the plain and is exposed to floods) and 2) The Zigali house (situated in the hillside and is exposed to earthquakes). These types have formed and improved gradually based on the experience and knowledge of consecutive generations and achieved an acceptable harmony with their surroundings; so it is essential to pick out and document these building types and identify their capabilities against disasters.

After the assessment of mentioned types, capabilities and their promotion potentials, the following results were achieved:

1- Rural residential types have shown an acceptable attitude towards disasters in previous decades.
2- Shakili foundations are stable enough to resist heavy floods due to its weight and construction method, although it needs improvements in the process of wood preparation.
3- The zigali houses are light enough to be earthquake resistant and can be constructed rapidly due to their simple implementation technique.
4- Promotion strategies needed to be applied in vernacular construction methods to increase disaster mitigation measures of such building types. (e.g. Chemical treatment of wood, reinforcing joints of wood structure)
5- Small modifications can provide settlements which are more resistant against natural disasters and are acceptable for utilization as contemporary construction.

5. References

BEIC (1900), Condensed Statement on the Construction of Earthquake-proof Wooden Buildings, Bulletin of the Earthquake Investigation Committee in Foreign Languages, English, Tokyo, Japan.

Earthquake Reconstruction and Rehabilitation Authority (ERRA), Guidelines for the compliant construction of Leepa-type timber post and beam houses, English, Islamabad, Pakistan.

Iftekhar Ahmed, K. (2005), Handbook on design and construction of housing for flood-prone rural areas of bangladesh, Asian Disaster Preparedness Center (ADPC), English, Dhaka, Bangladesh.

Khakpour, Mojgan (2007), Construction of shakili houses in Guilan, Fine art periodicals, 25, Persian, Iran

Mazhar Sarmadi, Nastaran, Rastgouy Haghi, Seyedeh Hoda (2010), A comparative study of rural residential types in Northern Iran based on their technical capabilities, Participatory Design and Appropriate Technology for Post-Disaster Reconstruction, i-REC 2010, English, India.

Memarian, Gholamhossein, 2005, Recognition of residential architecture of Iran (Outward type), Iran University of Science & Technology publications, Persian, Iran

Rastgouy Haghi, Seyedeh Hoda, Mazhar Sarmadi, Nastaran (2010), Typology of rural housing in Northern Iran, Participatory Design and Appropriate Technology for Post-Disaster Reconstruction, i-REC 2010, English, Ahmed Abad, India.

Stephenson, Maggie; Schacher , Tom (2006), Basic training on Dhajji construction, Earthquake Reconstruction and Rehabilitation Authority (ERRA), English, Mansehra, Pakistan.

Zargar, Akbar et al (1993), Typology of Guilan rural housing based on architecture and materials, NDRII, Persian, Tehran, Iran.

(2001), Details for Conventional Wood Frame Construction, American Forest & Paper Association, American Wood Council, English, Washington DC, United States.