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Seismicity vulnerability assessment of Garlat, Balakot-Pakistan using rapid visual screening

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ABSTRACT

The study was conducted in the Garlat area of Balakot city to assess the infrastructural vulnerability to natural disasters and the related level of awareness among community. A household questionnaire based survey was used to determine awareness and resilience of the community. Another methodology named Rapid Visual Screening (RVS) was used to determine the factors that contribute to infrastructure vulnerability to natural disasters. Factors assessed through this methodology are vertical and plan irregularity, soft storey, soft hazards, multiple storeys and building codes. Questionnaire results show that 70% people are educated and 90% are aware of high risk of area to natural disasters. 71% respondents still suffer from psychological trauma. More than 60% respondents want to leave the area but are unable to do so because of lack of governmental support. More than 72% people have no reach to information on future disasters. Ninety percent buildings are being built without codes. Almost 50% buildings are reinforced cement concrete (R.C.C) and contribute to vulnerability. Other factors are vertical irregularity, plan irregularity, soft storey and falling hazards which are 60%, 50%, 50% and 58% respectively. The study concludes that more than half of the population in Garlat is vulnerable to natural disasters.

Keywords: Vulnerability, Natural disasters, Rapid visual screening, Risk factors

INTRODUCTION

Natural disasters are powerful and well known mechanisms of nature, responsible for causing direct and indirect release of hazardous materials. This results in the loss of life, property damage and destruction of ecosystems *(*Marzo *et al.,* 2015*).*Seismicity is defined as the worldwide or local distribution of earthquakes in space, time, and magnitude whereas vulnerability is defined as the degree to which a system or a part of a system may react adversely during the occurrence of a hazardous event *(*Proag, 2014*)*. Natural disasters occur all over the world and affect both developed and developing countries but some populations are more vulnerable than others and depend upon areas that are more exposed to natural hazards. To decrease the number of deaths and people affected by natural disaster, population living in a specific area should understand their level of exposure and vulnerability to some specific hazard *(*Balica *et al.,* 2015*)*. Since we cannot control these natural events, the only option left behind is to build structures that are resistant to the impacts of these strong seismic forces. In this manner, different evaluation processes can be carried out as a part of seismic vulnerability assessment. Seismic vulnerability assessment or evaluation is defined as an approved process or methodology of evaluating deficiencies in a building that prevents the building from achieving a selected performance objective. On the basis of such an assessment, a building can be demolished, improved or retrofitted or altered to decrease its seismic demands *(*El Betar, 2016*).*

The idea of vulnerability has been defined in a variety of ways. In general, vulnerability is the

Author's Contribution: L.S. & U.H., Did research, data analyzed, concept & designed stud; N.S. & A.M. Did data acquisition & prepared manuscript

range of potential to be harmed by natural hazards and issued to describe and measure the extent to which a community's structure, services or environment is likely to be damaged or disrupted by the impact of an event *(*Wei *et al., 2004).*Vulnerability in the context of disaster can be defined as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard (Fotopoulou & Pitilakis, 2013)*.* Conventional vulnerability assessment concentrates on infrastructural vulnerability. Infrastructure refers to the built environment of a community which is essential for proper functioning of a community thus including houses, schools, hospitals, roads etc.

Implementing the building codes resistant to a natural disaster is a major approach towards dealing with natural disasters effectively because most earthquake fatalities and extensive property damage result from buildings that collapse (Wang, 2014)*.* Fortunately, modern building codes and a progressive engineering community have reduced the risk of loss for newer homes and buildings in many developed countries. However, investment should be made to retrofit or replace older and potentially vulnerable structures, including schools and hospitals (Kovacs, 2010). In 2004, world faced large scale destruction due to tsunami and the concerns raised to reduce the disaster risks all over the world. In 2005 United Nations, in collaboration with many countries, came up with a disaster reduction plan named Hyogo Framework of Action. HFA is a 10 year plan intended to reduce the risk of damage caused by natural or man-made disasters (Chen & Eckles, 2014). A study was conducted in Italy to assess the seismic risk to the reinforced concrete hospital buildings; therefore, two Italian hospitals were selected damaged by 2009 L'Aquila Earthquake and the 2012 Emilia Earthquake. The assessment involved the use of Rapid Visual Screening method to determine a Safety Index for hospital buildings using questionnaire method, the results of which were compared with that of a push-over analysis. The two methodologies suggest that this procedure can be used to evaluate the seismic risks of important buildings (Perrone et al., 2015). The methodology that was used to assess the infrastructure of the selected site is named R.V.S (Rapid Visual Screening) suggested by FEMA (Federal Emergency Management Agency), USA. This method has been useful in terms of visual analysis of infrastructure seismicity *(*Perrone *et al., 2015).*

The present study was carried out in Balakot tehsil, subdivision of Mansehra District in the North-Western Province of Pakistan, located at about thirty-eight kilometers north-east of the city of Mansehra. It has an average elevation of 971 meters (3188 feet). Balakot is a small town located on the bank of the river Kunhar that cuts the city in two halves and has population of about 24000 People. The city has a history of natural disasters and has great risks of land sliding, earthquakes and sometimes thunderstorms and has already suffered from these disasters *(*Hung *et al., 2016).* The earthquake of 2005 completely destroyed the city had a death toll of 80,000 but exact number is still unknown. The community named Garlat was selected in Balakot city for research *(*Mishra *et al., 2017).* The main purpose of this study was to find out the factors that contribute to infrastructural vulnerability in order to reduce risk of damage and to assess the knowledge of people regarding their vulnerability to natural disasters, their mitigation and building techniques (Nanda & Majhi, 2014).

MATERIALS AND METHODS

Study site

Garlat is located just above the river Kunhar which is the study site in district Mansehra of Tehsil Balakot. People in Garlat were mostly poor and unable to leave the area due to lack of access to resources and governmental support. During the data collection, it was observed that people were still living in the shelters provided by the Saudi government since the 2005 earthquake and couldn't rebuilt their houses. There are many factors that contribute to the vulnerability of the area to natural disasters such as poverty, lack of awareness, buildings on slopes, poor building techniques. Mostly infrastructure is built on slopes and with poor building materials and techniques *(*Du *et al., 2016)*. People of Garlat were supposed to be moved to a safe area but due to some political reasons this plan has been neglected. Resultantly, people are forced to live in the same area with high risk. So the site of Garlat was selected to identify the factors that contribute in its vulnerability to natural disasters.

Tool used for study

Rapid visual screening (RVS) was used to screen the vulnerable building in the current study. Additionally, a questionnaire based survey was also conducted to evaluate the awareness of people regarding the vulnerability of the area to natural disasters and the factors that contribute to their vulnerability. 100 buildings including residences, schools, commercial, hospitals and mosques were surveyed in the areas of Garlat using RVS method. 100 households were also selected forth primary data collection via questionnaires and interviews.

RVS (Rapid Visual Screening) Method

RVS method was first published in 1988 with FEMA 154 (Federal Emergency Management Agency): a handbook written for the identification of seismically hazardous buildings. It has a wide number of users ranging from engineers, building officials to properly trained nonprofessionals. It is also called a "sidewalk survey" as it requires the screener only to move around the building and to note down the basic description of building, its layout, occupancy, and a rapid structural evaluation related to its seismic hazard. It ranks the buildings into two categories:

Category I: Buildings which require no further evaluation and acceptable seismic performance

Category II: Buildings which do require further evaluation and are seismically hazardous

RVS does not require any calculations and is easy to implement. It takes only 10-15 minutes to survey a building. The data is then recorded onto a special data collection form. Following are the steps of the procedure used:

i. Selection of the site
ii. Acquirement of seismicity maps of the site
iii. Selection of data collection form according to the seismicity of the site
iv. Field screening of the building which includes;
   a. Building address and design date
   b. Number of storeys
   c. Building name
   d. Occupancy
   e. Number of persons living in a building
   f. Inspection of building for its vertical irregularity
   g. Inspection for plan irregularity
   h. Determining the soil type
   i. Identification of falling hazards
   j. Photographing the building

These parameters determine the extent of vulnerability of a building to a natural disaster. In this study, high seismicity zones of the selected area were surveyed and thus the High Seismicity Data Collection form was chosen.

Questionnaire as study tool

A questionnaire based survey was also conducted in the areas under study. Survey consisted of primary data collection by direct interviews with households. The questionnaire composed of the following sections; personal profile of the respondent, risk factor, psychological factor, socio-economic factor, preparedness status of community, infrastructural factor. A pilot study comprising of 20 respondents for questionnaire based survey and 20 buildings for Rapid Visual Screening was also performed. This helped in improving the methodology and questionnaires after which the main study was conducted.

Data analysis

The data acquired was assessed by using software SPSS 16. Descriptive analysis of data was done collected by questionnaire. Correlation was done for some parts of data collected by Rapid Visual Screening. Relation between different factors has been represented using bar graphs.

RESULTS

The result of study has shown the overall condition of population in Garlat Balakot who were at higher risk of future disasters.

Table I: General Data of Respondents

Variable	% response
Gender	
Male	64
Female	36
Age	
20-30	41
31-40	40
41-50	14
>50	5
Education	
Nil	19
Primary	11
Matriculation	29
Secondary	19
Higher	22

Table-I shows that male respondent dominated the female with 64% and 34% respectively. Most of the respondents were educated and mostly the level of education was matriculation and 19% of respondents were illiterate. Most of the respondents (approximately 78%) have been living in Garlat since their birth which indicates that population has less resources to move away from a high risk area.

Information about the socio-economic factors

It showed that 31% people had monthly income between 15,000 to 20,000 PKR and 75% had more monthly expenses than their income mostly because of inflation. 91% of the respondents have suffered property loss close to twenty millions in the 2005 earthquake. Most of the respondents have received funds from the government but these funds have been unable to make up the losses they have suffered.

Table II: Data about the socio economic factors of respondents

Variables	% response	Variables	% response
Monthly Income		**Funds from the government**	
5000-10,000	24	Yes	87
10,000-15,000	15	No	10
15,000-20,000	31	Somewhat	3
>20,000	30	**Ever wanted to leave the area**	
Monthly Expenses		Always	55
<1000	3	Sometimes	12
1000-5000	9	Never	33
5000-10,000	13	**Factors that force to live in this area**	
>10,000	75	Poverty	35
Cost incurred from 2005 earthquake		Property	13
0-50,000	3	Family	27
50,000-100,000	2	No governmental support	20
100,000-2,000,000	91	Other	5
>2,000,000	4		
Cost to rebuild homes			
0-50,000	24		
50,000-100,000	11		
100,000-500,000	49		
>500,000	16		

Most of the respondents said that they want to leave the area to some safe zone but they are forced to live in this high risk area because of the factors given in Table II.

Preparedness status of community

Table-III shows that the preparedness level of the community is very poor. 72% of the respondents said that community is never informed about the risk of a disaster. 86% of respondents told that government has never been given a plan to follow in case of a disaster. Only 39% respondents said that training is provided sometimes in order to get prepared for a disaster. 42% of the respondents said that community uses mosques for announcements as an alarm system to inform about the upcoming flood. 84% of the respondents said that there is no organization working for the disaster preparedness in the community.

Table III: Descriptive analysis on information about preparedness status of Garlat community for natural disasters

Variables	% response	Variables	% response
Is community informed before disaster		**Is there any alarm system in the community**	
Always	10	Always	42
Some-times	18	Some-times	7
Never	72	Never	51
Is a plan given to follow before disaster		**Is there any organization working in the community**	
Always	4	Always	11
Some-times	10	Some-times	5
Never	86	Never	84
Is training provided before disaster			
Always	8		
Some-times	22		
Never	70		

Table IV: Information about Infrastructural Factor

Variables	% response	Variables	% response
Status of the area after earthquake		**Do you know about retrofitted buildings**	
Destroyed	99	Yes	56
Partially destroyed	1	No	38
No effect	0	Somewhat	6
New building plan		**Is there any retrofitting in area**	
Yes	4	Always	None
No	79	Sometimes	10
Somewhat	17	Never	69
What kind of buildings are mostly built		Uncertain	21
Engineered	3	**Satisfaction level with building plan**	
Non-engineered	97	Yes	24
Building codes		No	45
Always	2	Somewhat	31
Sometimes	8		
Never	90		

Information on Infrastructural Factor

When the earthquake of 2005 occurred, the whole community was destroyed. About 79% of the respondents said that there has been no building plan after the earthquake. Around 97% of the buildings have been built without any engineered consultation. As many as 86% of respondents said that there has been no visit of any authority to inspect the infrastructure of the area and 90% of buildings are built without application of seismic codes. About 56% of the respondents were aware about the retrofitted buildings and only 10% said that there has been retrofitting in the area. Only 24% of the respondents are satisfied with the new somewhat building plan. Rest of the respondents is unsatisfied with the little help that government provided. Results are shown in table-4

Table V: Different Types of Building Materials Used in Garlat Community and Their Description

No.	Building type	Description
1	Wooden	Complete use of wood without any reinforcement, may be light or hard wood
2	Wood with concrete	Wooden roofs and concrete pillars and walls
3	Concrete	Use of large concrete blocks with poor or no reinforcement
4	Reinforced cement concrete (R.C.C)	Use of concrete with steel reinforcement
5	Metal frame	Complete use of light weight metal frame (shelters), vulnerable to fire
6	Metal frame with concrete	Light weight metal frame roofs and concrete walls with poor reinforcement
7	Clay	Complete use of clay, very rare

Most of the buildings that were surveyed are residential and commercial. There was very small number of hospitals in Garlat. Schools and mosques are in good number. Most of the buildings are constructed by R.C.C building code. The buildings built with R.C.C code are mostly double storey. After R.C.C, most buildings are built with concrete blocks with poor reinforcement. Most people in Garlat are living in the metal frames and concrete houses. People living in such houses are mostly poor and are unable to construct them a new house so they continue to live in those shelters by building concrete rooms along the shelter.

The study showed that more than 50% buildings have vertical irregularity i.e. built on slopes which are more vulnerable. Figure-1 shows that most of the buildings in Garlat are vulnerable due to vertical irregularity. Plan irregular structures are known to suffer more during a seismic activity. About 50% of the infrastructure in Garlat is having plan irregularity.

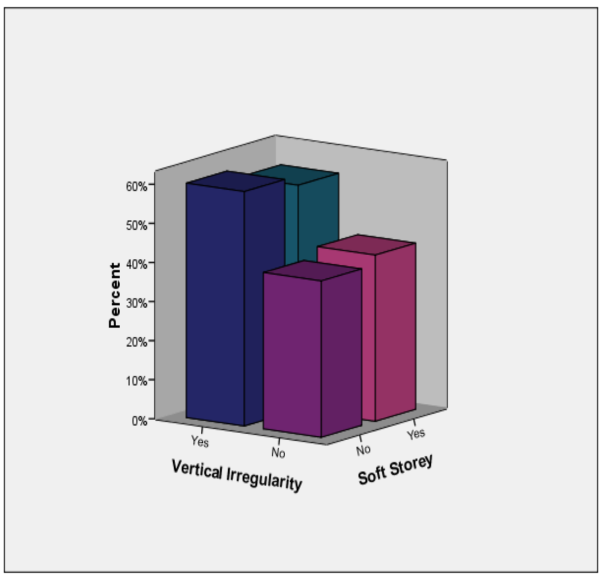

Fig. 1: Percentage and association of the buildings having both vertical and plan irregularity

Soft storey is a ground storey that has less number of walls to support and it is weaker than above storeys *(*Sadat*, 2010).* A structure having a soft storey also has poor seismic performance. In such structures, soft storey failure causes the whole building to collapse. Figure-2 shows the presence of two contributing factors at the same time. Figure shows that more than 50% of the structures having vertical irregularity also have soft storey.

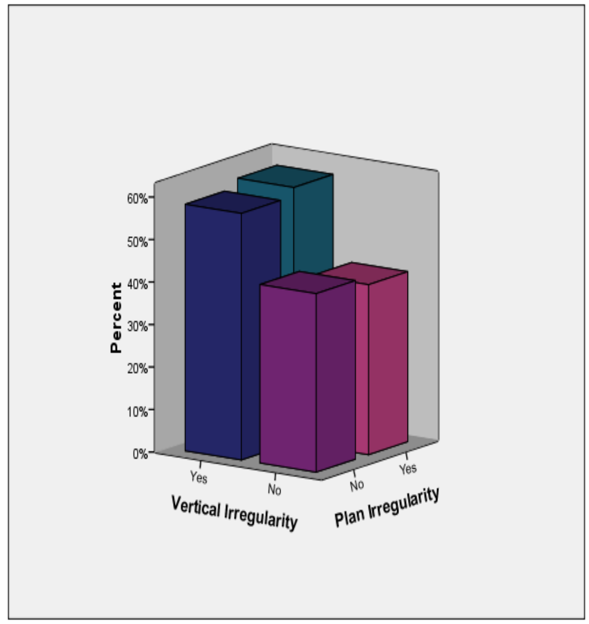

Fig. 2: Percentage & association between buildings having both vertical irregularity and soft storey

Figure-3 shows the percentage of buildings having different number of storeys and their vertical irregularity.

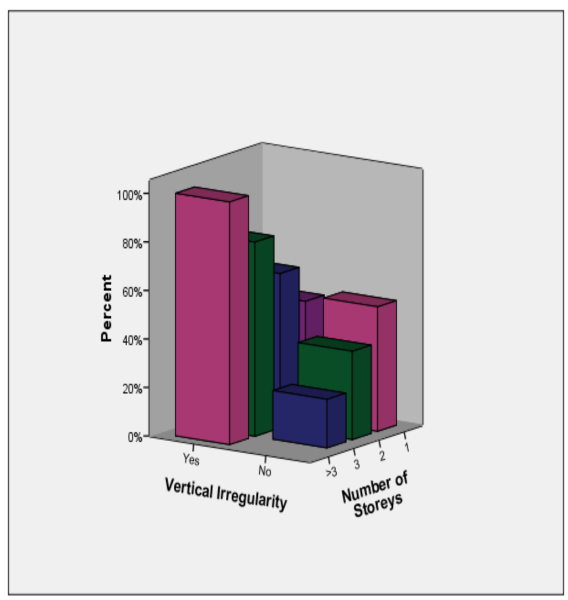

Fig. 3: Association between vertical irregularity and number of storeys

Through rapid visual screening three types of falling hazards were identified in Garlat which are unreinforced chimneys, heavy overhangs and balconies. Figure-4 shows that about 60% of structures in Garlat have falling hazards out which 40% are heavy overhangs.

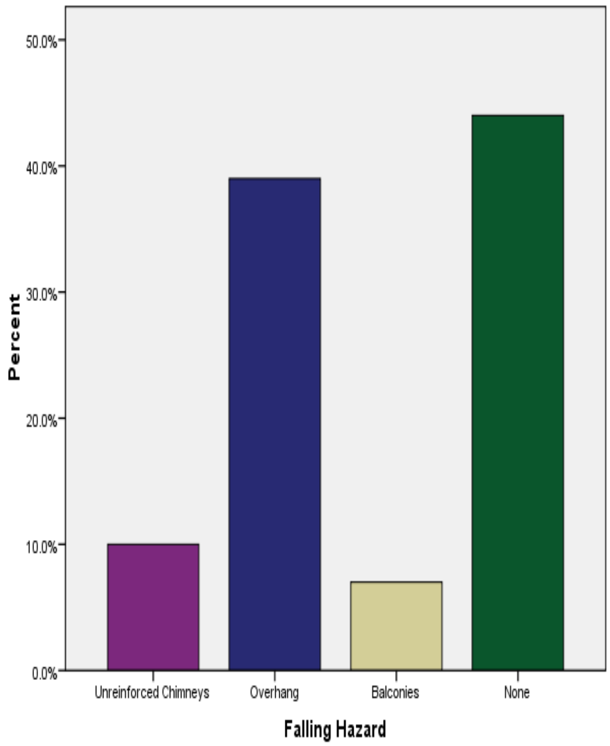

Fig. 4: Percentage of buildings having falling hazards

Falling hazards have negative effect on the seismic response of a building. If the building itself does not collapse during seismic activity, these falling hazards may fall and may contribute to death toll. Some other falling hazards are parapets and heavy cladding which is not identified in Garlat. Figure-5 shows the application of building codes after the 2005 earthquake. There was huge application of codes immediately after the earthquake in years 2006 to 2007.

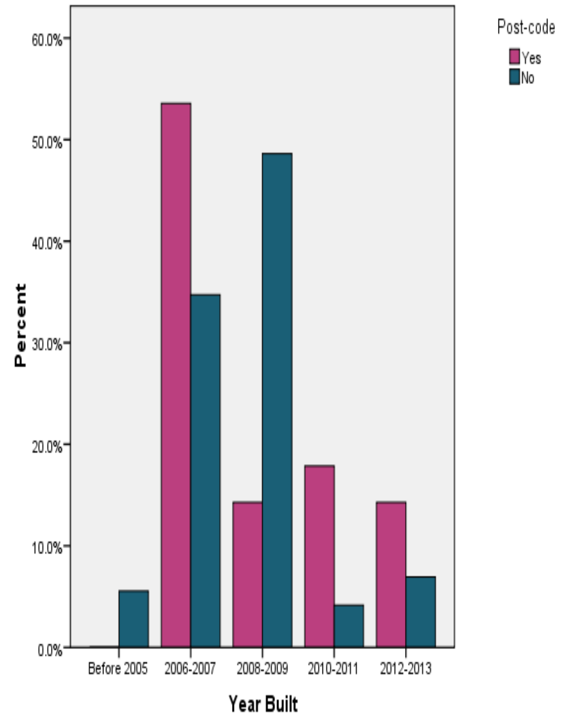

Fig. 5: Association between year in which building is built and the application of building codes

DISCUSSION

Infrastructure of a community has a significant role during a natural disaster *(*Zio*, 2016)*. Most large structures like schools and hospitals can be providing shelter when a disaster occurs. More resilient structures will promote the positive seismic response of a community reducing its vulnerability to a disaster. Therefore, there is a need of proper architectural assistance while building a community in a disaster-prone area. Disaster resistant design and seismic building codes must have kept in mind while construction. In 2005, Kashmir earthquake struck the whole country, Pakistan, precisely northern districts of NWFP, Federal Capital and Azad Kashmir. Balakot was one of the areas that had the worst hit and was destroyed. Balakot has been declared a red zone in a seismic survey of the quake-affected area by the Provincial Earthquake Rehabilitation Authority (PERA) in the light of seismic reports submitted by experts from Turkey, China and Norway. After this declaration, Government of Pakistan decided to not allow the people to construct in this red zone area and initiated a separate construction project, in the area named Bakryal, which was given to Earthquake

Rehabilitation and Reconstruction Authority (ERRA). This project was supposed to settle more than 30,000 household but after two years it left its work undo and many people were left shelter less. Time passed and the Pakistan Government disappointed the people and left them in the same way due to which people began reconstruction in the red zone.

According to the survey, more than 70% of the respondents are forced to live in the red zone due to lack of governmental assistance. The poverty of this area is high due to which people cannot afford living in the safe zone. People are not aware about the risk of the disaster and do not have any plan to follow if a disaster occur. People living in Balakot are aware of the natural disasters that can occur. The people have built their own houses. Earthquake do not kill people, building do. Most people have built their houses using different old and techniques. Types of houses were identified which are wooden, wood with concrete, concrete blocks, reinforced cement concrete (R.C.C) metal frame, metal frame with concrete and clay. 46% houses are made of R.C.C which is forbidden in the area. Despite this people continue to build structures with poor seismic performance. A great factor contributing to the vulnerability of the community is the construction on the steep slopes. Slopes are naturally unstable. Gravity, wind, water or disturbance, either natural or man-made, can cause mass movement, erosion, slippage or slide *(*Aryal*, 2014).* About 60% houses are built on slopes in Garlat. Plan irregularity may be in E, L, T, U, or + shapes and can cause torsion. It can occur in all building types. Damage at connections may significantly reduce the capacity of a vertical-load-carrying element, leading to partial or total collapse *(*FEMA *154, 1988).* 50% buildings in Garlat are seen to have plan irregularity. Soft storey is a ground storey that has less number of walls to support and it is weaker than above storey. Soft storey is intentionally left open for the purpose of parking or any other purpose *(*Bonati and Mendes *2014).* Soft storey buildings are known to have poor seismic response. When earthquake occurs the walls of soft storey are unable to carry the load and collapse. More than 50% buildings in Garlat have a soft storey. Height of a structure is sometime related to the amount of damage that it may undergo. Multi storey buildings on soft soil may experience a longer shaking *(*Dhutta *et al., 2016).* In Garlat more than 50% buildings have double storey. Triple storey buildings are rarely seen.

Non-structural falling hazard such as chimneys, parapets, overhangs, heavy balconies, and heavy cladding can pose life-safety hazards if not adequately anchored to the buildings. In Garlat almost 60% buildings have falling hazards 40% of which are heavy overhangs. Others are balconies and unreinforced chimneys. Seismic building codes result in earthquake resistant buildings, but not earthquake proof buildings. Seismic codes intend to protect people inside buildings are preventing collapse. Structures built according to code resistant minor earthquakes are undamaged, resist moderate earthquakes without significant structural damage and resist severe earthquakes without collapse. The devastation caused by 2005 earthquake in Pakistan raised questions on the adequacy of the present design in construction practice in the country. Government of Pakistan appointed a Committee of technical experts to suggest modifications to the present codes for earthquake resistance designed of buildings. There is a lack of awareness for seismic protection in many parts of the country.

CONCLUSION

The study has concluded that the community of Garlat is still highly vulnerable. Despite of the fact that the area falls into the red zone category, people still lived in area. The main reason behind it was the lack of governmental support to the community. The new Balakot city has been left incomplete because of inability of ERRA which was supposed to provide homes to 30,000 families of Balakot. People living in area of Garlat were well aware of the being vulnerable to natural disasters but they had no choice to go without any support. People in Garlat were rarely informed about the upcoming disasters and had never being given any preparedness plan by the district governments. The only alarm system was through the mosque announcement. More than half of Garlat people were living on the steep slopes which make them more vulnerable to earthquake, floods and landslides. Most houses were built with poor material and with no engineering assistance.

Buildings had irregular shapes and heavy overhangs. There is a dire need of governmental assistance for better and up-to-date design and construction in the area of Garlat.

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