An integrated vulnerability assessment of earthquake and flood prone area: A case study of Muzaffarabad

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A thesis submitted in partial fulfillment of the requirements for the degree of MS Urban & Regional Planning

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1 THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of the thesis titled “An integrated vulnerability assessment of earthquake and flood prone area: A case study of Muzaffarabad” written by Mr. Atif Habib (Registration No. 00000278130), of Urban and Regional Planning (NIT-SCEE) has been vetted by the undersigned, found complete in all respects as per NUST Statutes/Regulations, is free of Plagiarism, errors and mistakes and is accepted as partial fulfillment for the award of MS degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

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Date: ____

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Date: ____

DEDICATION

This thesis is dedicated to my beloved parents, teachers, brothers and friends for always being an unending source of love and encouragement.

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All praises to the Allah Almighty, the merciful and the most beneficent who showers his blessings upon us every day. He beholds all the knowledge of the universe and beyond.

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Atif Habib

ABSTRACT

All around the globe, natural hazards like earthquakes and floods are on the rise, posing a danger to people and infrastructure and significantly increasing the life losses and economic issues related to them. Some areas are prone to more than one hazard at a time, making it very essential to assess the vulnerability of that area collectively, considering all the hazards and different aspects of vulnerability. Physical and social dimensions of vulnerability may influence the vulnerability against one hazard directly and the other indirectly. This research explores the physical and social aspects of vulnerability against both earthquakes and floods in Muzaffarabad, as it is prone to both hazards. For this, well-established indicators were used. The sample size was calculated using Yamane's method, and 420 questionnaires were collected. The RVS (Rapid Visual Survey) method was used for physical vulnerability indicators. Indices were made using selected indicators for physical vulnerability against flood, physical vulnerability against earthquake, total physical vulnerability, social vulnerability, and overall total vulnerability. Then these indices were compared for urban and rural areas. Results show that the people in urban areas are physically more vulnerable to earthquakes than rural areas. Whereas people in rural areas are socially more vulnerable than in urban areas. There is not much difference in the physical vulnerabilities of both areas against flood. The results imply an urgent need to formulate and implement updated disaster risk reduction strategies.

Table of contents

Contents

Table of figures

List of tables

2 Introduction

2.1 Background

Pakistan is prone to several natural hazards, and various disasters occur almost every year. Moreover, the frequency of disasters has increased over the last few decades around the globe and in Pakistan. The main disasters in Pakistan responsible for most damage are floods, earthquakes, cyclones, droughts, and landslides. Compared to the 20th century, the number and frequency of disasters increased significantly in this century, and it is increasing exponentially. According to a report published by CRED, 315 different events of disasters occurred in 2018 only, which affected around 68 million people (CRED 2018). During 1998-2017, around 1.35 million people lost their lives due to natural disasters (UNISDR 2017). According to another report by CRED, 6873 natural disasters occurred around the globe between 1994 and 2013, which caused 1.35 million deaths. This averages 68000 lives per year. Besides this, the number of people affected by disasters during this 20-year period was approximately 218 million (CRED 2015).

Pakistan has been placed frequently among the top ten (in terms of deaths) in the countries affected most by climate-related activities such as floods, heat waves, storms, etc. In 2015, Pakistan was ranked 10th in the Global Climate Risk Index among the countries most affected by weather-related events . Similarly, Pakistan was placed 5th in 2014 while 1st in 2010 in the climate risk index. From 1980 to 2014, 8887 events of disasters were recorded in Pakistan according to the DESINVENTAR database (LEAD 2015). Among all these events, floods contributed the maximum with a percentage of 47%. The maximum number of deaths during this period was due to the 2005 earthquake. During 1980-1990, the average number of deaths recorded was 750 persons per year. This number increased to 3541 deaths annually during 1990-2014. Besides the death toll of the 2005 earthquake, the number of deaths per year still rose significantly during the first decade of the 21st century compared to the last few decades of the previous century (LEAD 2015).

2.2 Problem statement

As we know, Pakistan is prone to various natural hazards, but two of them contributing to the most losses are earthquakes and floods. According to the profile of natural hazards in Pakistan by NDMA, earthquakes and floods are on top in almost every major aspect, such as the number of events per year, deaths per event, affected people per event and losses per event. Figures of drought for affected people and losses per event are higher than earthquakes and floods, but their frequency is far below these two disasters, which makes them the most dangerous among all disasters. For earthquakes, the number of deaths per event is 3900 and the number of people affected per event is 22,00,000, while those for floods are 136 and 565,236 respectively (NDMA 2012). Losses due to different disasters in developing countries like Pakistan are very high mainly due to the higher physical vulnerability of their buildings (Khan, Qureshi et al. 2019).

Some areas in Pakistan are highly prone to earthquakes as well as a flood at the same time. District Muzaffarabad is one of them. It is highly prone to both earthquakes and floods (NDMA 2012). It was severely affected during the 2005 earthquake. This is why Muzaffarabad is selected as a study area for this research.

2.3 Research questions

1. What is the physical vulnerability of buildings against earthquakes and floods?
2. What are the socio economic factors that affect physical vulnerability?
3. What are the challenges faced by institutions in reducing physical vulnerability?

4. What should be the strategies and policies to reduce the physical vulnerability of buildings against earthquakes and floods?

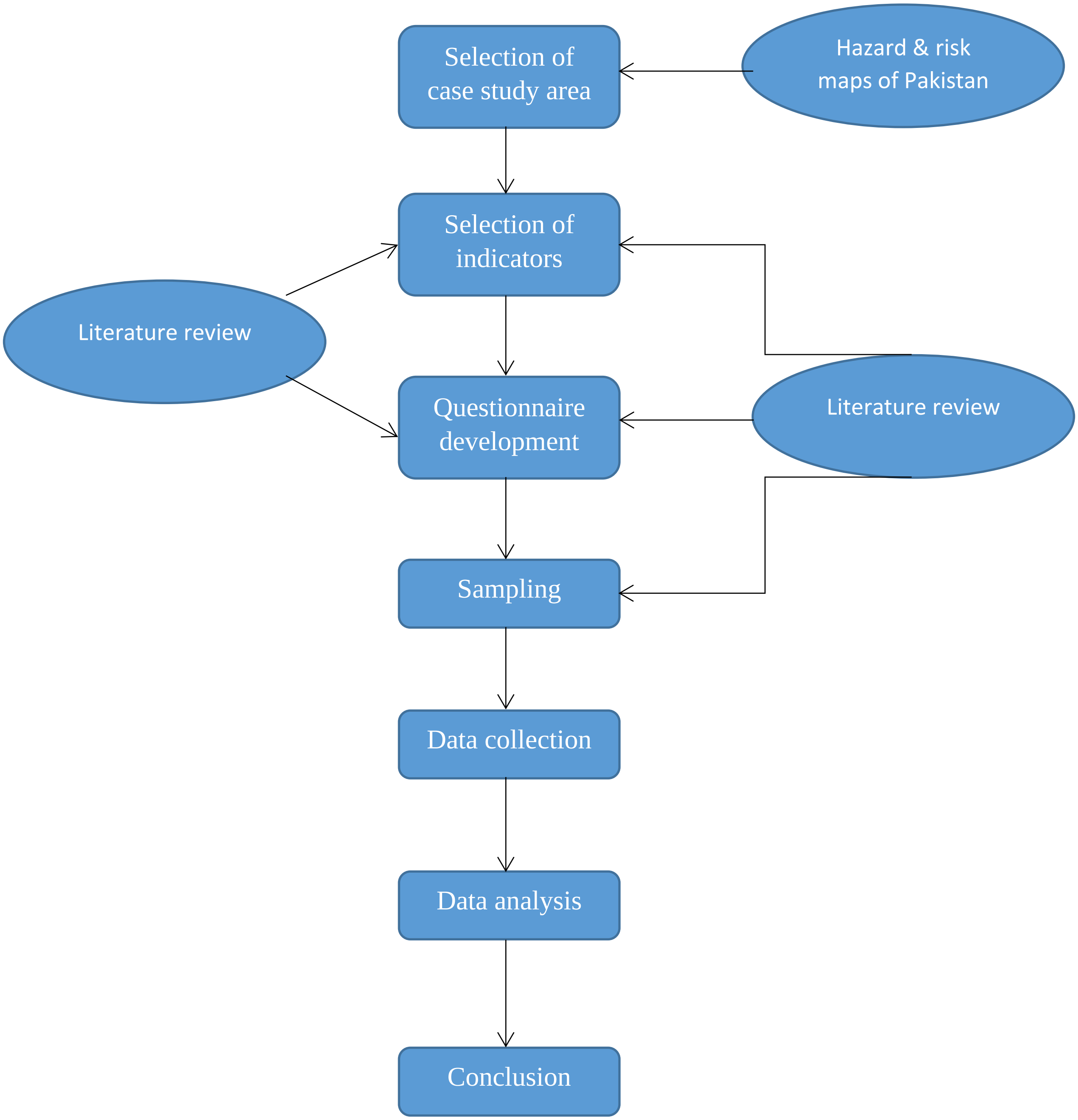
2.4 Research objectives

1. To compare the physical vulnerability of buildings against earthquakes and floods.
2. To compare socioeconomic vulnerability against earthquakes and floods.
3. To identify challenges and issues faced by the institutions in reducing vulnerability.
4. To suggest strategies/policies for reducing physical vulnerability against earthquakes and floods.

2.5 Scope of the study

The purpose of this study is to identify the factors affecting the physical vulnerabilities of buildings against earthquakes and floods separately, as well as how these factors affect the physical vulnerabilities for earthquakes and floods when taken collectively, as the study area is prone to both earthquakes and flood. Besides this, this study aims to identify the challenges faced by different departments to reduce the physical vulnerability of buildings. As Pakistan is a developing country, there is less focus on disaster risk reduction by preparing well before the disaster occurs. So, this study aims to explore the factors that affect the physical vulnerability of buildings and suggest strategies to reduce it.

2.6 Conceptual framework



3 Literature review

3.1 Earthquake hazard

Hazard is defined by a study as an event that has the capability to cause injuries, loss of lives and infrastructural damage (Khan, Qureshi et al. 2019). An earthquake is a disaster with an enormous destructive capacity, can affect a vast area, and is very threatening to human life and infrastructure (Zhang, Xu et al. 2017). All around the globe, natural hazards like earthquakes are rising, posing a danger to people and infrastructure and significantly increasing the life losses and economic issues related to them. Countries like Pakistan (developing countries) are more susceptible to these damages, as their population is less aware of the natural hazards and their buildings are physically more vulnerable to them. (Khan, Qureshi et al. 2019). The 2005 earthquake (Mw 7.6) in the Kashmir valley reportedly cost more than 100 thousand lives and destroyed major infrastructure in the area (Yousuf, Bukhari et al. 2020). Earthquake vulnerability assessment is the main part of the disaster risk reduction process (Khan, Qureshi et al. 2019). Due to the ongoing northward drift of the Indian plate, and its collision with the Eurasian plate, the Himalayan region, including Kashmir and other northern parts of Pakistan, are highly prone to earthquake hazard (Joshi, Ghildiyal et al. 2019) (Khan, Qureshi et al. 2019). Earthquakes caused huge losses in urban Asia and other developing countries, which is an alarming issue. Therefore, it is very important to conduct studies assessing the physical vulnerability of buildings (Khan, Qureshi et al. 2019). It is difficult to predict many disasters, especially earthquakes, accurately. Thus, reducing vulnerability is the core component of disaster risk reduction, which assesses the vulnerability of hazard-prone areas very crucial (Zhang, Xu et al. 2017). Pakistan has been hit by an earthquake many times, and the most severe one in the recent past was that of 2005, in which nearly 73,000 people lost their lives, almost 80,000 got injured, and 2.8 million people were displaced. Recent studies also show that there are strong chances of structural as well as human losses in case of any future occurrence of big earthquake in Pakistan (Khan, Qureshi et al. 2019).

3.2 Flood hazard

Natural hazards like floods and earthquakes pose a constant threat to the world's population (Kodag, Mani et al. 2022). Flood has been referred to as one of the most damaging natural hazards all around the world, extensively damaging the natural and built environment and highly disturbing human settlements. People living in plain and hilly areas are seriously affected every year (Shreevastav, Tiwari et al. 2021). A study suggests that there are different levels of damage due to floods in different areas, that is due to the differences in vulnerabilities of those areas. That is why it is important to make policies keeping in view the vulnerability of any area against any hazard (Jha and Gundimeda 2019). According to a study, flood vulnerability is the characteristics of an individual or group in terms of their susceptibility, exposure, and resilience against flood hazards. Exposure is the presence of individuals in the flood-prone area due to which they can be exposed to losses in case of a flood; susceptibility refers to the tendency of people and their belongings to get affected by a disaster due to the fragility of communities, authority's capacities and policies and geographical context, while resilience is the ability of society or individuals to resist, cope with and recover in case of any disaster (Imran, Sumra et al. 2019). Asia has been hit by many severe disasters in the past and can be referred to as the supermarket of disasters like floods and earthquakes (Khan, Qureshi et al. 2019).

3.3 Vulnerability

As the term "vulnerability" has a diverse use therefore, many scientists and scholars have defined it in a variety of ways according to their disciplines. A study stated that a large number of authors having technical backgrounds or related to the natural sciences define physical vulnerability as “the degree of loss to a given element, or set of elements, within the area affected by a hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss)”. A study defined vulnerability as the pre-disposition or propensity of a system to be affected adversely by an external stressful event. In disaster risk reduction, vulnerability can be understood in terms of the circumstances and characteristics of a system that make it susceptible to the effects of a disaster. Besides core components of vulnerability, there are also five thematic dimensions of it, including human, economic, social, natural, and physical aspects (Jamshed, Rana et al. 2019). According to another study, there are two schools of thoughts on vulnerability, first considers the risk of exposure of an environmental system to a possible natural disastrous event. In contrast, the second focuses on the risk of natural hazards to the social unit in terms of human lives and building structures (Antwi, Boakye-Danquah et al. 2015). A study gives a general definition of vulnerability as the potential for loss in case of any natural disaster. Losses may differ depending on time, space, and societies. Vulnerabilities of different societal groups also change with space and time. It means that from time to time, updating vulnerability for any population or area is crucial for disaster management (Cutter, Boruff et al. 2012). Vulnerability is one of the basic components of risk perception. Thus, it is very important to assess the vulnerability for making disaster risk reduction strategies (Khan, Qureshi et al. 2019). Previously the importance of vulnerability against hazards has been overlooked but when a hazard interacts with a vulnerable population, especially one with huge scale and intensity, it is very likely to turn into a severe disaster (Healey, Lloyd et al. 2022). The Intergovernmental Panel on Climate Change (IPCC) has defined vulnerability as the “degree to which a system is prone to and unable to cope with adverse effects of climate change, including climate variability and extreme weather conditions” (Antwi, Boakye-Danquah et al. 2015). The basic components of vulnerability (sensitivity and adaptive capacity) are internal and non-observable; thus, they cannot be measured directly. Therefore, vulnerability is assessed by employing suitable indicators and their quantifiable parameters for its components (Sharma and Ravindranath 2019). Irrespective of spatial extent and magnitude, the adverse effects of a disaster are connected to the vulnerability of elements which are at risk (buildings, infrastructure, and people). Therefore, it is clear that quantification and proper analysis of vulnerability is necessary for risk reduction strategies (Fuchs, Keiler et al. 2019). According to a study, disasters are the outcome of an interaction between the hazard and vulnerability, which means that by reducing vulnerability, the chances of hazard becoming disaster can be reduced. It makes vulnerability assessment very crucial as addressing the underlying causes which contributes to vulnerability can help in preventing disasters (Arifeen and Nyborg 2021). The climate risks and losses caused by disasters are not exclusively due to the actual hazard only, but it is also determined by the economic and societal conditions that effect the preparation and response of people to that disaster (Birkmann, Jamshed et al. 2022). The risk of hazards in urban areas must be studied from both hazard and vulnerability perspectives. Still, the vulnerability component in urban systems may be more influential than the hazard component (Kodag, Mani et al. 2022). Vulnerability assessment is a pre-disaster activity that can positively influence policy making and disaster mitigation by giving the authorities an insight into people's condition (Imran, Sumra et al. 2019). A study conducted in Bangladesh suggests that RVS methodology by FEMA is better for assessing vulnerability in areas with different construction types, including katcha houses (Rahman, Ansary et al. 2015). Vulnerability assessment in urban environment is still a major scientific challenge worldwide (Boukri, Farsi et al. 2018). Capacity and vulnerability assessment of communities in hazard-prone areas are integral to formulating effective disaster risk reduction policies (Jamshed, Rana et al. 2019). Assessing vulnerability of buildings and then carrying out their restoration and rehabilitation can reduce the possible damages caused by future earthquake event (Khan, Qureshi et al. 2019). Assessment of different types of vulnerabilities has become an important field for research. Disasters always occur when potentially hazardous natural events interact with the social, physical, environmental, or economic characteristics of any vulnerable population. Thus, it is very important to study the hazard, as well as different vulnerabilities (social, physical, environmental economic) of exposed population. It is identified as a key activity by Hyogo framework to develop "systems of indicators of disaster risk and vulnerability at national and sub-national scales" (Kappes, Papathoma-Koehle et al. 2012).

3.4 Physical vulnerability

A study defined physical vulnerability as the chances of the physical component of a building unit getting damaged in case of any natural disaster. According to that study, physical vulnerability assessment is an important part of risk assessment and introducing risk reduction policies. Many recent studies have now focused on physical vulnerability assessment. This study also found that physical vulnerability and risk perception positively correlate, which means that assessing physical vulnerability is very helpful in policy making (Khan, Qureshi et al. 2019). Many authors argued that although assessment of damages is the most important aspect in assessing physical vulnerability, it should not be limited to the degree of loss only. They define vulnerability as "it is a characteristic of human behavior, physical and social environments, describing the degree of susceptibility to the impact of natural hazards" (Kappes, Papathoma-Koehle et al. 2012). Housing is recognized as an important part of vulnerability by Sendai Framework for Disaster Risk Reduction (Healey, Lloyd et al. 2022). A study done on the buildings in the Austrian Alps has used physical vulnerability indices and vulnerability curves for vulnerability assessment for dynamic flooding. That study says that the physical vulnerability index (PVI) can give the basis for policy-making in regard of vulnerability reduction (Papathoma-Köhle, Schlögl et al. 2022). Vulnerability has multi-dimensions (physical, economic, social etc.) (Gao, Ding et al. 2021), but its physical dimension is directly related to the losses and threats to human lives (Fuchs, Keiler et al. 2019). Different researchers are using different methods to assess physical vulnerability. This includes the simple methods of rapid visual screening and observational sidewalk surveys as well as complex ones like non-linear finite element analysis. The rapid visual screening method has been used in the countries like Portugal, Algeria, Bangladesh, Austria, Turkey, and India. Whereas complex non-linear procedure has been used in Egypt and Jordan by researchers (Khan, Qureshi et al. 2019). According to a study, the simplest method to assess the vulnerability against any hazard is to link the occurred disaster with possible hazard using disaster loss data. But this technique is not precise due to the inaccurate data on losses. Another technique is using different indicators to assess vulnerability (Imran, Sumra et al. 2019). Sendai framework and Sustainable Development Goals (SDGs) also stressed the importance of vulnerability assessment for disaster risk reduction (Jamshed, Rana et al. 2019).

3.5 Social vulnerability

A study defined socio-economic vulnerability as the state of communities, groups, or individuals in terms of their capacity to adopt and cope with any external stressful event. It can also be defined as the inability of individuals, organizations, or societies to resist the negative effects of any external event (Antwi, Boakye-Danquah et al. 2015). Social vulnerability along with community resilience, has emerged as the most important concept for describing the capability of society to prepare and adapt to the risks of environmental hazards (Ran, MacGillivray et al. 2020). A study describes social vulnerability as “it is the ability to deal with disasters” (Zhang, Xu et al. 2017). Another study says that mostly social vulnerability is described by the individual’s indicators only, such as age, gender, education, etc. Instead, those factors must also be considered in assessing social vulnerability that shapes or influence the ability of various groups to respond or susceptibility to getting harm during any disaster.

The study pointed out that the social aspect of vulnerability is often neglected, which is why most of the time, post-disaster loss/cost estimation reports lack information on social losses. It may be because socially created vulnerabilities are hard to measure (Cutter, Boruff et al. 2012). For making effective disaster risk reduction policies to reduce and control the damage caused by any disaster, it is crucial to not only study the hazard itself, but also to get information on sense of exposure and assess the social vulnerability of the hazard-prone area. The findings of social vulnerability assessment can be used for risk reduction and management decisions (Zhang, Xu et al. 2017). According to a study, social vulnerability deals with the fragility of people or society in terms of social, economic and political elements that determine the societal capacity or ability to respond in a disaster (Imran, Sumra et al. 2019). Another study says that vulnerability is built socially and exhibits inequalities among different social groups and places. Thus, reducing vulnerability requires accurate insight into underlying social and economic contexts for proper policy formulation. It is also confirmed by much research around the globe that the need to assess the social aspects of vulnerability is crucial as it is lacking in most vulnerability research. It is necessary to compile data of social aspect of vulnerability before formulating policies to determine accurately how best individuals and communities can cope with and recover from disasters (Dintwa, Letamo et al. 2019).

3.6 Integrated vulnerability assessment

Many places around the globe are vulnerable to more than one hazard at a time. Many studies regarding vulnerability assessment deal with the assessment of vulnerability against single hazard, but in recent past few studies also stressed the multi-hazard approach. UNEP (1992) already called for adopting a multi-hazard approach to assessing vulnerability and reducing disaster risk. Sometimes, steps taken to reduce the risk of one disaster in an area may increase the vulnerability to another disaster in that area. The Johannesburg plan (2002) also focuses on multi-hazard risk assessment. It refers to it as a basic element in analyzing vulnerability and disaster management for a safer globe in this century (Kappes, Papathoma-Koehle et al. 2012). A study on vulnerability assessment in Bangladesh adopted the integrated technique and assessed the vulnerability of buildings against earthquake and fire hazards using both physical and social vulnerability indicators (Rahman, Ansary et al. 2015). A study shows that social indicators to assess flood vulnerability are directly affected by the socio-economic conditions but get their contribution from indirect effects of physical features, including land tenure. This study concluded that assessing social and physical aspects of vulnerability separately cannot give the true picture of vulnerability. Collective analysis of both is crucial for making policies to reduce vulnerability (Imran, Sumra et al. 2019). Another researcher has done the integrated seismic vulnerability assessment of buildings using the RADIUS Model (Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disaster) (Boukri, Farsi et al. 2018).

3.7 Similar studies (international)

A study done in the Faucon municipality, Barcelonnette Basin, France, adopted almost the same four-stepped approach as used in this study, i.e., identifying the study area and relevant hazards in that area, determining the most relevant indicators, and collecting the data, weighting of indicators and at last identifying the effects of different hazards on overall vulnerability. This study also suggests that the methodology used for assessing physical vulnerability in an the alpine environment can be used by other researchers or end users in any other environment according to their objectives (Kappes, Papathoma-Koehle et al. 2012). A study compared the social vulnerabilities of southern California and North Carolina against multi-hazards and found that assessing social vulnerability helps to recognize those factors that enable individuals and communities to respond and recover from natural disasters (Cutter, Boruff et al. 2012). A study assessing the physical vulnerability of buildings to dynamic flooding concluded that indicator-based techniques for physical vulnerability assessment are on the rise and these methods are good substitutes for vulnerability curves (Papathoma-Köhle, Schlögl et al. 2022). Another study conducted in Uttarakhand, India, assessed the physical vulnerability of lifeline buildings, including hospitals, police stations, administrative offices, emergency and fire service buildings, etc., using the same methodology as adopted in this study (Joshi, Ghildiyal et al. 2019). A study in Sichuan province, China, covered four dimensions- socioeconomic, demographics, buildings, and infrastructure to assess the vulnerability against earthquakes (Zhang, Xu et al. 2017). A study in Dhaka, Bangladesh, uses the same RVS methodology to assess the vulnerability against earthquake and fire hazards (Rahman, Ansary et al. 2015).

3.8 Similar studies (national)

A study conducted in Bhakkar, Pakistan, incorporated both socio-economic and physical indicators, as used in this study, to assess flood vulnerability and suggested that linking socio-economic conditions of households with their geographical conditions gives a more clear picture of vulnerability for the formulation of sustainable resilience policies (Imran, Sumra et al. 2019). A study in Malakand, Pakistan, used the RVS methodology to collect the data for the selected indicators for assessing physical vulnerability to earthquake hazards (Khan, Qureshi et al. 2019). This study will also use the same approach for assessing both physical and social aspects of vulnerability to earthquakes and floods. Another study on IPCC 2014 framework suggests that assessing vulnerability for any hazard by using appropriate indicators for sensitivity and adaptive capacity is practically very useful, as these two are the drivers of vulnerability, and addressing them offers a reliable approach for reducing current vulnerability and managing potential risks (Sharma and Ravindranath 2019).

4 Methodology

4.1 Research design

This study assesses the physical vulnerability of buildings in areas prone to earthquakes and floods, determines the effects of social elements on physical vulnerability, and identifies the hurdles institutions face in reducing vulnerability. This study is quantitative and qualitative in nature (mixed research method). Both primary and secondary data are used during this research. A closed-ended questionnaire was designed to collect data from people in the study area, while officials from concerned departments were interviewed using open-ended questions.

4.2 Selection of case study area

District Muzaffarabad was selected as the study area, which is the capital of AJ & K (Azad Jammu & Kashmir). It is located in the northern areas of Pakistan. The total area of Muzaffarabad is 1642 sq.km. According to 2017th census, the population of Muzaffarabad is 0.65 million, and the population density is 396 persons per sq.km. The population in an urban area is 171,959, whereas the total number of people living in rural areas is 478,371. Muzaffarabad is ranked 2nd in AJ & K based on its population. District Muzaffarabad is further divided into 3 tehsils named Garhi Dopatta, Muzaffarabad, and Pattika. This area was selected as the study area because it is highly prone to earthquakes and floods, according to hazard map of Pakistan (NDMA).

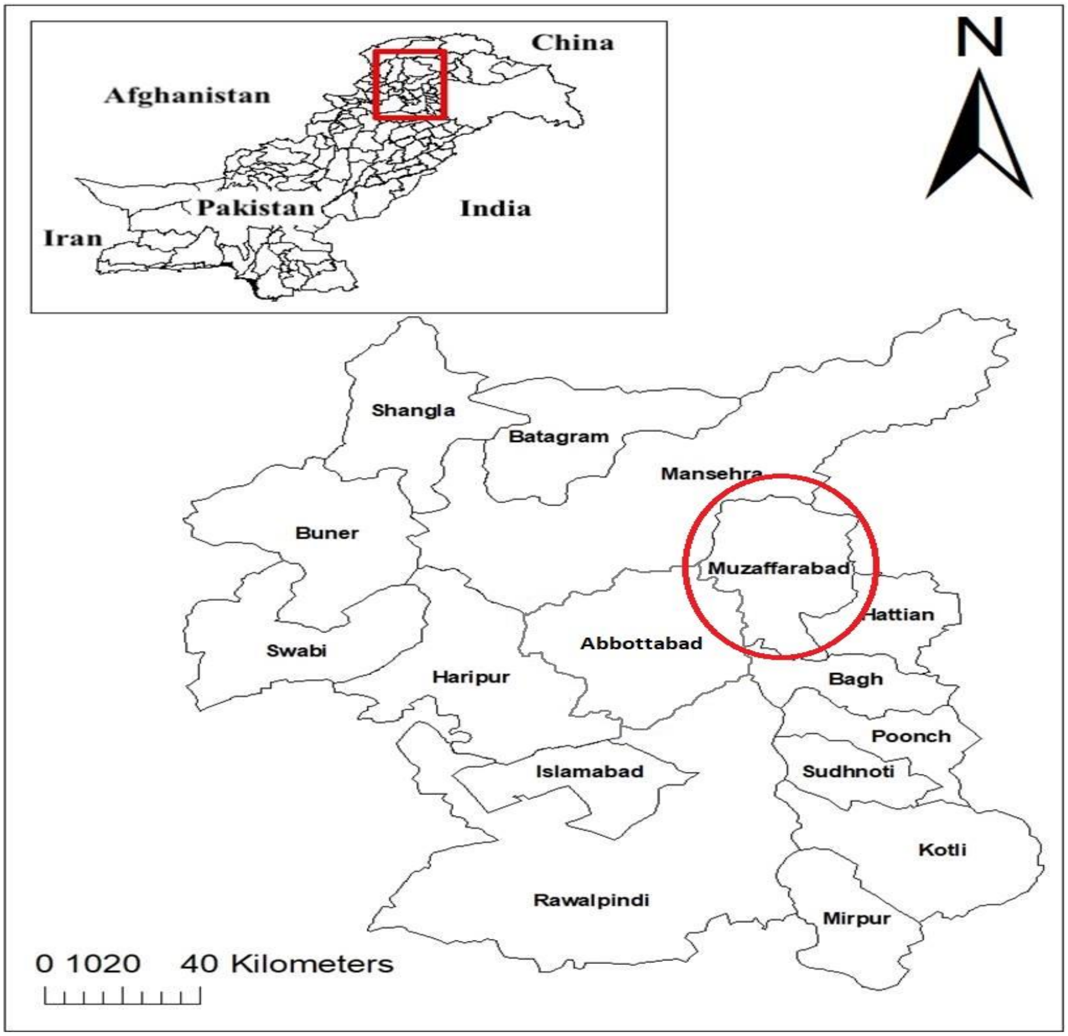


Figure 1 Map of Muzaffarabad

4.3 Questionnaire development

For data collection from the study area, a questionnaire was designed containing two portions. The first one included the closed-ended questions based on physical vulnerability indicators and was filled using the rapid visual survey (RVS) method. The second portion of the questionnaire consisted of closed-ended questions based on social indicators and was filled during the field survey by interviewing the respondents. All the physical and social indicators for earthquake and flood vulnerability were selected by reviewing literature and then consulting professionals. The open-ended questions for interviewing officials from concerned departments were designed with the consultation of professionals.

4.4 Physical vulnerability indicators

Indicators for assessing physical vulnerability to earthquakes and floods are shown separately in the tables below.

4.4.1 For earthquake

Table 1 Indicators for earthquake

S. No	Indicator	Classes	References
1	Building type	Unreinforced Stone masonry Unreinforced Block masonry Unreinforced Brick masonry RC Frames with infill walls	(Kappes, Papathoma-Koehle et al. 2012), (Khan, Qureshi et al. 2019), (Ortega, Vasconcelos et al. 2019), (Joshi, Ghildiyal et al. 2019), (Boukri, Farsi et al. 2018), (Khan, Qureshi et al. 2019)
2	Building Age (years)	< 10 10-30	(Kappes, Papathoma-Koehle et al. 2012), (Khan, Qureshi et al. 2019), (Zhang, Xu et al. 2017),

		>30	(Boukri, Farsi et al. 2018)
3	Plan irregularity	Regular Slight Irregularity Irregular	(Khan, Qureshi et al. 2019), (Ortega, Vasconcelos et al. 2019), (Joshi, Ghildiyal et al. 2019), (Boukri, Farsi et al. 2018), (Khan, Qureshi et al. 2019)
4	Vertical Irregularity	Regular Slight Irregularity Irregular	(Khan, Qureshi et al. 2019), (Ortega, Vasconcelos et al. 2019), (Joshi, Ghildiyal et al. 2019), (Boukri, Farsi et al. 2018), (Khan, Qureshi et al. 2019)
5	Number of Story	1 2 3 >3	(Kappes, Papathoma-Koehle et al. 2012), (Khan, Qureshi et al. 2019), (Ortega, Vasconcelos et al. 2019), (Joshi, Ghildiyal et al. 2019), (Rahman, Ansary et al. 2015), (Khan, Qureshi et al. 2019)
6	Building Apparent Construction Quality	Good (good connection between structural	(Khan, Qureshi et al. 2019), (Joshi, Ghildiyal et al. 2019), (Boukri, Farsi et al. 2018),

		elements) Medium Poor (poor connection between structural elements)	(Khan, Qureshi et al. 2019)
7	Maintenance condition	Well Maintained Poorly Maintained	(Kappes, Papathoma-Koehle et al. 2012), (Khan, Qureshi et al. 2019), (Joshi, Ghildiyal et al. 2019)
8	Wall Type	Stone Block Brick	(Khan, Qureshi et al. 2019), (Healey, Lloyd et al. 2022)
9	Apparent Material Quality	Poor Medium Good	(Kappes, Papathoma-Koehle et al. 2012), (Khan, Qureshi et al. 2019),
10	Mortar type	Mud Cement	(Khan, Qureshi et al. 2019)
11	Building site location	Hill top High slope	(Antwi, Boakye-Danquah et al. 2015), (Khan, Qureshi et al. 2019), (Joshi, Ghildiyal et al.

		Mild slope Plain	2019), (Boukri, Farsi et al. 2018)
12	Dampness	Damped Slightly damped Un damped	(Khan, Qureshi et al. 2019)
13	Maximum wall span	12 feet or less 12 to 20 feet More than 20 feet	(Ortega, Vasconcelos et al. 2019)
14	Previous Structural Damage	No visible damage Slight damage Severe damage with widespread cracks	(Ortega, Vasconcelos et al. 2019)
15	Minimum gap between adjacent Building	< 100 mm per story Otherwise	(Joshi, Ghildiyal et al. 2019)
16	Building Location	Internal Corner End Isolated	(Joshi, Ghildiyal et al. 2019), (Boukri, Farsi et al. 2018)

17	Soil type	Rock/Hard soil Medium Loose sand	(Joshi, Ghildiyal et al. 2019), (Khan, Qureshi et al. 2019)
18	Roofing Material	RCC Slab Wooden Asbestos Sheet	(Kappes, Papathoma-Koehle et al. 2012), (Joshi, Ghildiyal et al. 2019), (Healey, Lloyd et al. 2022)
19	Parapet	Secured Not Secured No parapet	(Joshi, Ghildiyal et al. 2019)
20	Heavy Mass at top	Yes No	(Joshi, Ghildiyal et al. 2019)
21	Construction type	Engineered Non-Engineered	(Joshi, Ghildiyal et al. 2019), (Khan, Qureshi et al. 2019)
22	Overhang Length; balcony (in meters)	< 1.5 >1.5	(Joshi, Ghildiyal et al. 2019)

4.4.2 For flood

Table 2 Indicators for flood

S. No	Indicators	Classes	References
1	Number of Stories	1 2 3 >3	(Kappes, Papathoma-Koehle et al. 2012)
2	Construction type	Katcha Mix Pakka	(Imran, Sumra et al. 2019), (Jamshed, Rana et al. 2019)
3	Basement	Present Not Present	(Kappes, Papathoma-Koehle et al. 2012)
4	Plinth Level	2 feet or less 2 feet to 6 feet More than 6 feet	(Kappes, Papathoma-Koehle et al. 2012), (Imran, Sumra et al. 2019), (Papathoma-Köhle, Schlögl et al. 2022)
5	Building site elevation	Plain Mid Slope High Slope of	(Antwi, Boakye-Danquah et al. 2015)

		Hill Hill Top	
6	Sewerage System	Present and Covered Present but not covered Not Present	(Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019), (Jamshed, Rana et al. 2019)
7	Age of building (in years)	Less than 10 10-30 More than 30	(Kappes, Papathoma-Koehle et al. 2012), (Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019)
8	Location W.R.T river	More than 200 feet Inside 200 feet Inside 100 feet Next to river	(Jamshed, Rana et al. 2019)
9	Building Construction on approved plan	Yes No	(Khan, Qureshi et al. 2019)
10	Presence of Side spaces	Not Present At one Side At both sides	
11	Boundary wall	Present	

		Not present	

4.4.3 Social vulnerability indicators

Social indicators that can affect physical vulnerability were also selected after reviewing the literature available. The list of social indicators used in this study is given below

Table 3 Social vulnerability indicators

S. No	Indicators	Classes	References
1	Household income (PKR)	Below 25000 25000 to 50000 50000 to 100000 Above 100000	(Khan, Qureshi et al. 2019), (Jha and Gundimeda 2019), (Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019), (Dintwa, Letamo et al. 2019), (Jamshed, Rana et al. 2019)
2	No of disabled persons	Zero 1 2 More than 2	(Antwi, Boakye-Danquah et al. 2015), (Jha and Gundimeda 2019), (Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019), (Jamshed, Rana et al. 2019), (Kodag, Mani et al. 2022)
3	Male to female ratio	<1 1	(Antwi, Boakye-Danquah et al. 2015), (Jha and Gundimeda

		>1	2019), (Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019), (Jamshed, Rana et al. 2019), (Kodag, Mani et al. 2022)
4	No of person in age group (0-6 years)	Zero 1 2 More than 2	(Antwi, Boakye-Danquah et al. 2015), (Khan, Qureshi et al. 2019), (Jha and Gundimeda 2019), (Cutter, Boruff et al. 2012), (Rahman, Ansary et al. 2015), (Imran, Sumra et al. 2019), (Dintwa, Letamo et al. 2019), (Jamshed, Rana et al. 2019), (Shreevastav, Tiwari et al. 2021)
5	No of person older than 60 years of age	Zero 1 2 More than 2	(Antwi, Boakye-Danquah et al. 2015), (Cutter, Boruff et al. 2012), (Zhang, Xu et al. 2017), (Rahman, Ansary et al. 2015), (Imran, Sumra et al. 2019), (Dintwa, Letamo et al. 2019), (Jamshed, Rana et al. 2019), (Shreevastav, Tiwari et al. 2021)
6	Family size	<5	(Khan, Qureshi et al. 2019),

		5 to 10 >10	(Zhang, Xu et al. 2017), (Imran, Sumra et al. 2019), (Dintwa, Letamo et al. 2019), (Jamshed, Rana et al. 2019), (Shreevastav, Tiwari et al. 2021)
7	House ownership	Owned Rented	(Khan, Qureshi et al. 2019), (Cutter, Boruff et al. 2012), (Dintwa, Letamo et al. 2019), (Jamshed, Rana et al. 2019), (Healey, Lloyd et al. 2022)
8	Household knowledge about disasters	NO Knowledge Only flood Only earthquake Both	(Antwi, Boakye-Danquah et al. 2015), (Cutter, Boruff et al. 2012)
9	Drinking water quality	Filtered Ground Water Municipal water supply Non-drinkable	(Antwi, Boakye-Danquah et al. 2015), (Jha and Gundimeda 2019), (Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019), (Jamshed, Rana et al. 2019), (Healey, Lloyd et al. 2022), (Kodag, Mani et al. 2022), (Birkmann, Jamshed et

			al. 2022), (Shreevastav, Tiwari et al. 2021)
10	Access to medical facility	Easy Medium No access	(Antwi, Boakye-Danquah et al. 2015), (Jha and Gundimeda 2019), (Cutter, Boruff et al. 2012), (Imran, Sumra et al. 2019), (Kodag, Mani et al. 2022), (Birkmann, Jamshed et al. 2022), (Shreevastav, Tiwari et al. 2021)

4.5 Sampling

For this research, data were collected from both urban and rural areas of Muzaffarabad. According to 2017th census, the total population of Muzaffarabad is about 650,000. Using Yamane's formula, the sample size was calculated using a confidence interval of 95% (e=0.05). Yamane's formula used is given below

$$n = \frac{N}{1 + Ne^2}$$

Where,

N = population size

E = error margin

n = sample size

According to above mentioned Yamane's sampling formula, 385 samples were required. However, 450 questionnaires were collected, and 420 were selected for further analysis after scrutiny.

4.6 Data analysis strategies

All the indicators of physical vulnerability for flood, earthquake and social vulnerability were assigned different categories according to their nature and after reviewing the literature. Then each category of every indicator was weighted from the lowest to the highest value. The lowest value was taken 0.20, and the highest one was 1.

Then these indicators were compared one by one for urban and rural areas. After that, by taking means of the values of each indicator, composite indices were made for earthquake physical vulnerability (EQPV), physical flood vulnerability (FPV), and social vulnerability (SV) using the following equation.

$$\boldsymbol{C1 = (W1 + W2 + W3 + W4 + \ldots Wn)/n}$$

After obtaining indices, each index was compared for urban and rural areas. Besides this, further indices were made for total physical vulnerability (by taking the mean of EQPV and FPV) and total vulnerability (by taking the mean of TPV and TSV), which were then compared for urban and rural areas.

$$\boldsymbol{TPV = (EQPV + FPV)/2}$$

$$\boldsymbol{TV = (TPV + TSV)/2}$$

Statistical Package for Social Sciences (SPSS) was used to enter data and to perform statistical analyses. Chi-square tests were used to identify differences between urban and rural areas.

Pearson’s correlation was used to establish the relationship between the earthquake physical vulnerability, physical flood vulnerability and social vulnerability. The correlation value can be in the range of -1 and 1. The sign of correlation shows the direction of the relationship, while the strength is denoted by a numeric value from -1 to +1.

5 Data Analysis

5.1 Physical vulnerability to flood

5.1.1 Type of construction

The type of construction is very crucial in case of a flood. Field data shows that in urban areas, only 1% of the houses are katcha while 96% of the houses are pakka. On the other hand, 40% of the houses in rural areas have mixed construction while 57% of the houses are pakka.

Table 4 Type of construction

Type of construction	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Katcha	1	0.4	4	2.9	0.000
Mix	9	3.2	56	40	
Pakka	270	96.4	80	57.1	

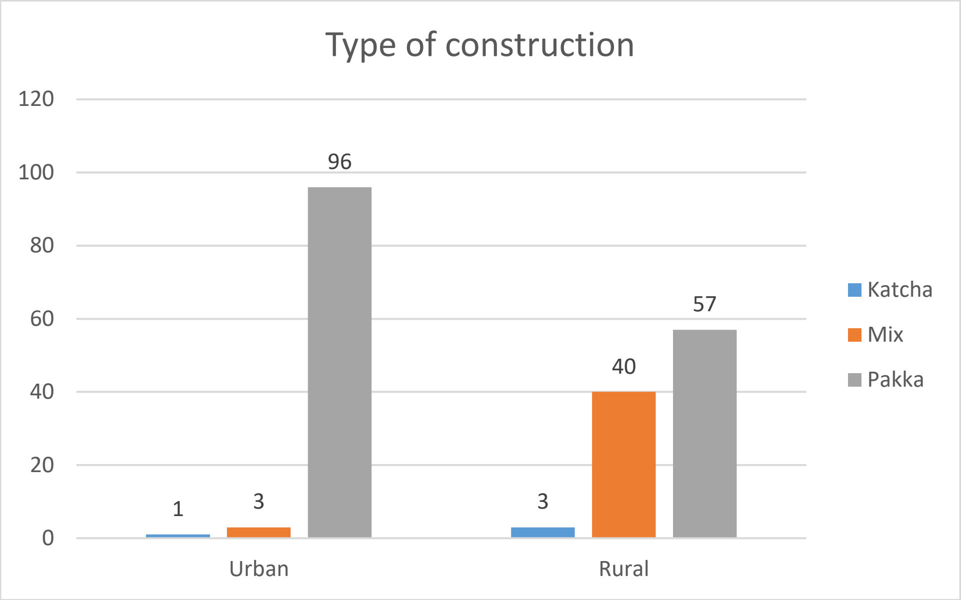


Figure 2 Type of construction

5.1.2 Location of building

Location of a house w.r.t river is very crucial in case of a flood. The field survey data shows that in urban areas, 45% of the houses are located beyond 200 meters of the river while 10% are located next to the river. On the other hand, 69% of the houses in rural areas are located beyond 200 meters distance from the river, whereas only 1% of the houses are located next to the river.

Table 5 Location of building

Location of building w.r.t river	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
More than 200 meters	125	44.6	96	52.6	

Inside 200 meters	71	25.4	41	26.7	0.000
Inside 100 meters	56	20	2	13.8	
Next to river	28	10	1	6.9	

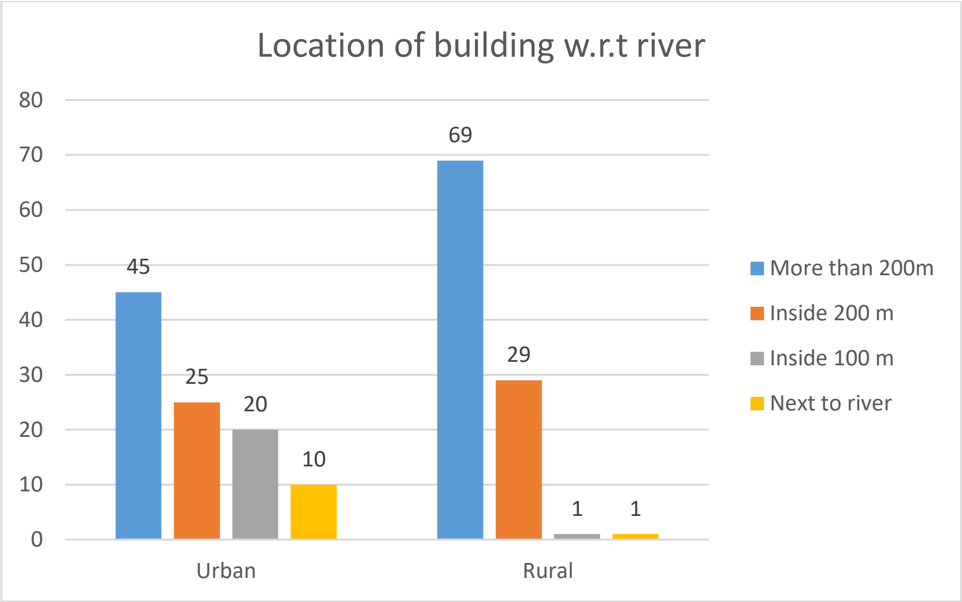


Figure 3 Location of building

5.1.3 Age of building

The age of the building has a major significance in deciding its vulnerability against flood. During field survey, it is found that 29% of the houses were built in the last 10 years while 41% of the houses are more than 30 years of age. On the other hand, only 14% of the houses in rural areas were built in the last 10 years, while 23% of the houses were older than 30 years.

Table 6 Age of building

Age of building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Less than 10 years	80	28.6	20	14.3	0.000
10 to 30 years	84	30	88	62.9	
More than 30 years	116	41.4	32	22.9	

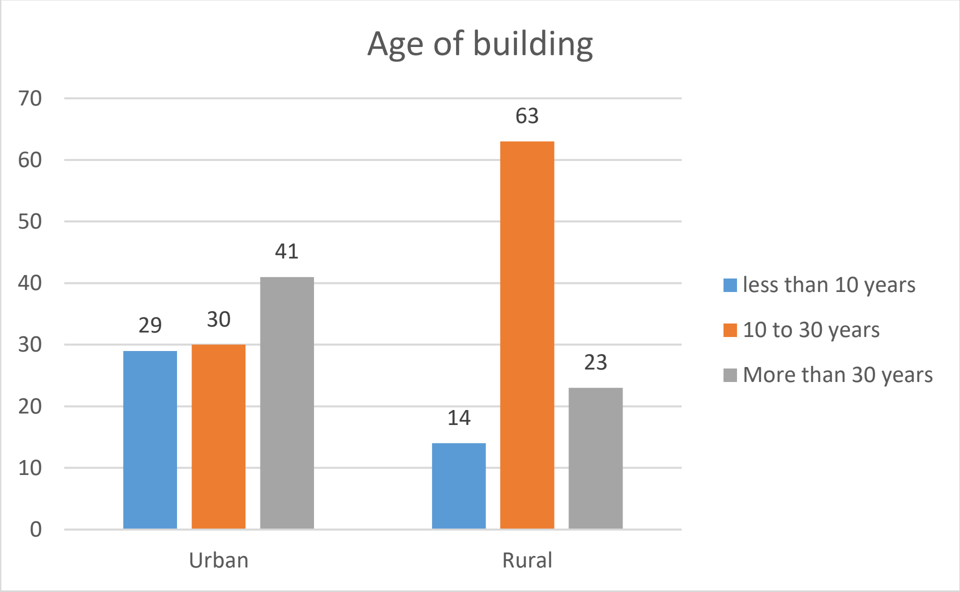


Figure 4 Age of building

5.1.4 Height of the lowest opening in building

The height of the lowest opening or plinth level in the building is a crucial indicator of flood hazard because the flood water enters the building at the lowest opening available. The results of the field data show that in urban areas, 7% of the houses have the lowest opening in the building below the ground level, 73% of the houses have the lowest opening under two feet from ground level, and only 20% of the houses have the lowest opening above 2 feet. In rural areas, 72% of the houses have the lowest opening under 2 feet from ground level whereas only 27% of the houses have the lowest opening above 2 feet.

Table 7 Height of the lowest opening

Height of the lowest opening in building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Below ground	21	7.5	12	8.6	0.049
0 to 2 feet	204	72.9	88	62.9	
2 to 6 feet	55	19.6	38	27.1	
Above 6 feet	0	0	2	1.4	

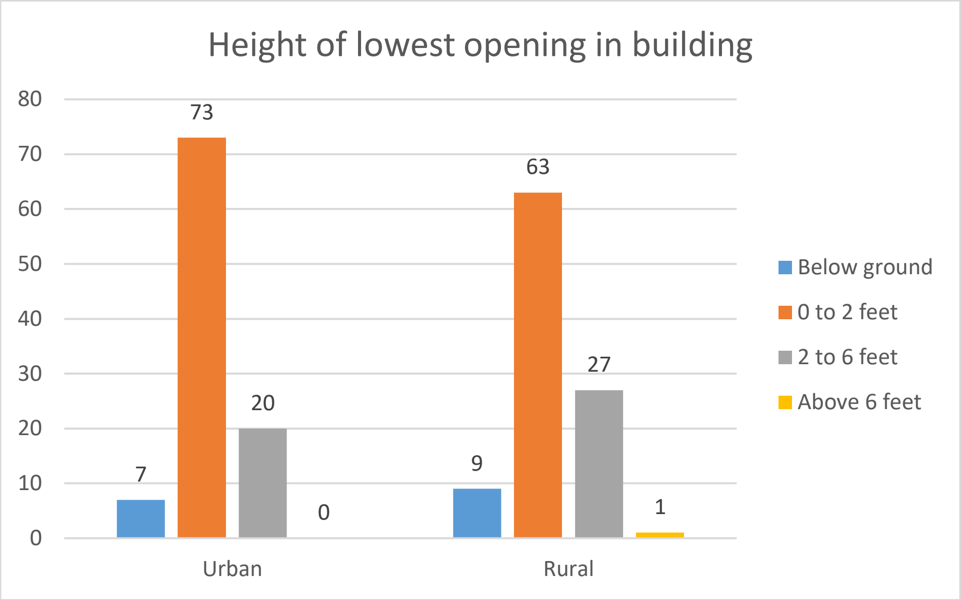


Figure 5 Height of lowest opening

5.1.5 Side spaces around building

In case of flood, the presence of side spaces around the building plays a significant role in protecting the building as side spaces allow the flood water to pass by, decreasing the pressure on the building. Field survey shows that in an urban area, 51% of the houses have no side spaces, 30% have side space at only one side of the building, whereas 19% of the houses have side spaces on both sides of the building. On the other hand, 83% of the houses in rural areas have side spaces at both sides of them whereas only 6% have no side spaces around them.

Table 8 Side spaces around building

Side spaces around building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Not present	144	51.4	8	5.7	

Present on one side	84	30	16	11.4	0.000
Present on both sides	52	18.6	116	82.9	

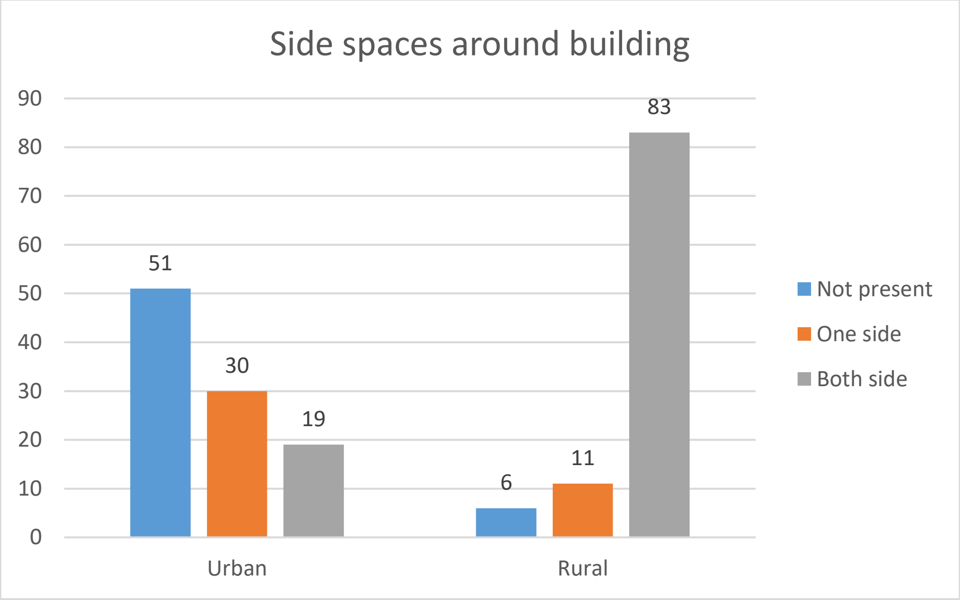


Figure 6 Side spaces

5.1.6 Presence of a boundary wall

The presence of a boundary wall around the house may play a positive role during flooding because it can protect the house from the initial impact of flood water. Data from a field survey shows that 60% of the houses in urban areas have walls, whereas 40% have no boundary wall around them. On the other hand, 83% of the houses in rural areas have no boundary wall, and 17% of the houses have a boundary wall around them.

Table 9 Presence of a boundary wall

Presence of a boundary wall	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Not present	112	40	116	82.9	0.000
present	168	60	24	17.1	

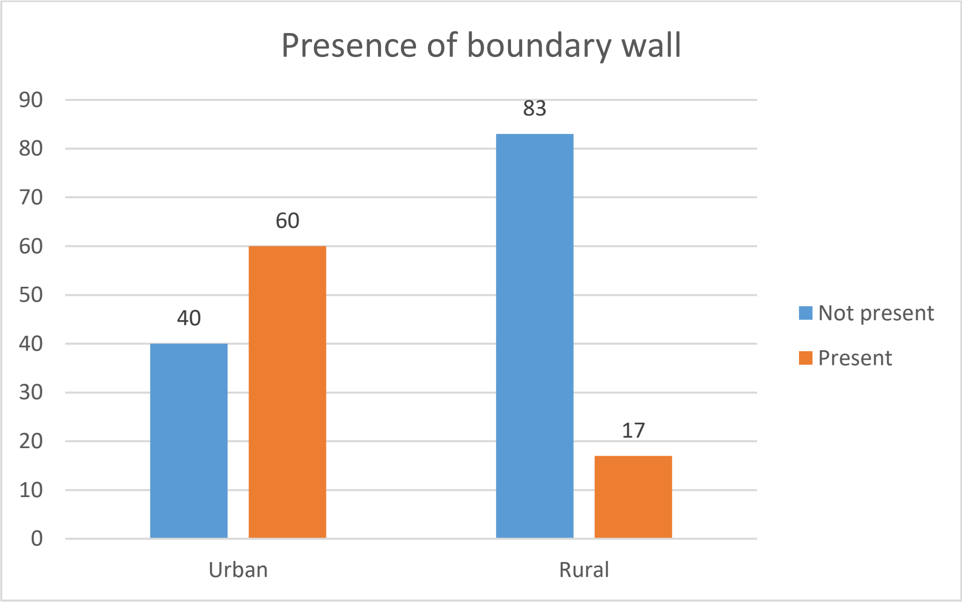


Figure 7 Presence of boundary wall

5.1.7 Ground terrain of the site

The ground train is also very important in case of flooding. Houses in plain areas may get affected more than those on the slope or top of the hill. Field survey shows that 41% of the houses in urban areas are located on plain terrain, while only 6% of the houses are located on the hilltop. On the other hand, 34% of the houses in the rural areas are located on the plain, and 10% of the houses are located at the hilltop.

Table 10 Ground terrain of the site

Ground terrain of the site	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Plain	115	41.1	47	33.6	0.002
Mild slope	101	36.1	36	25.7	
High slope of hill	47	16.8	43	30.7	
Hill top	17	6.1	14	10	

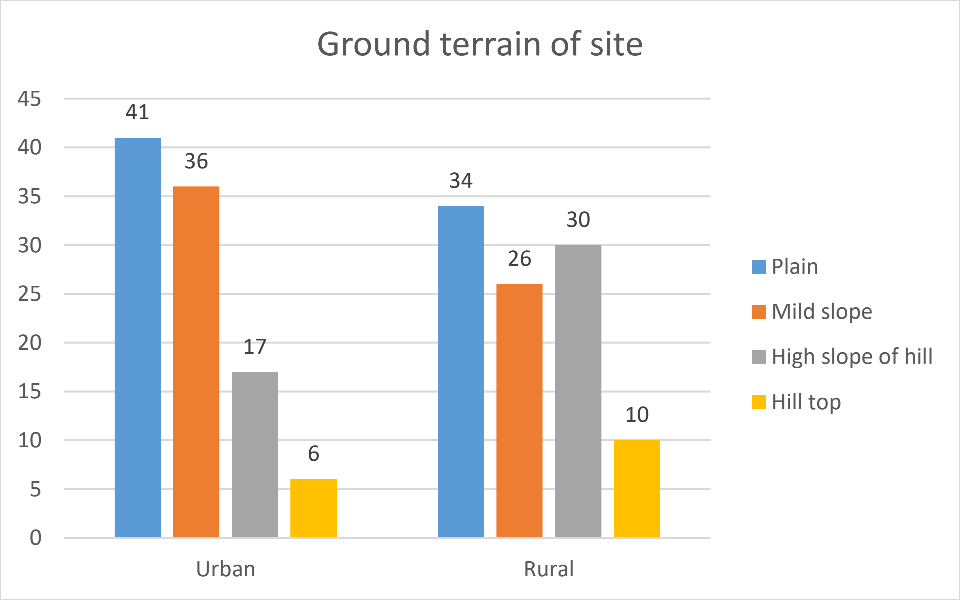


Figure 8 Ground terrain of site

5.1.8 Presence of basement

During flooding, the houses with basements are very vulnerable as water enters the basement very easily and can cause damage to property as well as human lives. During the field survey, it is found that in urban areas, 97% of houses have no basement, and in rural areas, there is no basement in 99% of the houses.

Table 11 Presence of basement

Presence of basement	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Present	4	1.4	4	2.9	0.257
Not present	276	98.6	136	97.1	

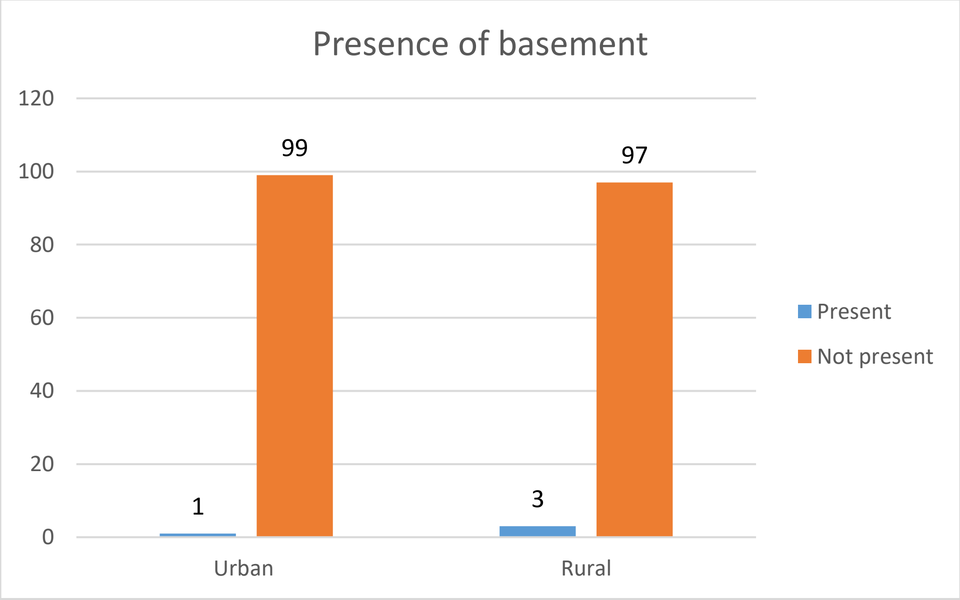


Figure 9 Presence of basement

5.1.9 Sewerage system

The presence and condition of a sewerage system in an area have a major significance in case of a flood. Data obtained during the field survey shows that 92% of the houses in urban areas are provided with a covered sewerage system, while only 8% have an uncovered sewerage system. On the other hand, a sewerage system is not present in 57% of the houses, and only 26% of the houses have a properly covered sewerage system.

Table 12 Presence and condition of sewerage

Presence and condition of sewerage	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Present and covered	258	92.1	36	25.7	0.000
Present but not covered	22	7.9	24	17.1	
Not present	0	0	80	57.1	

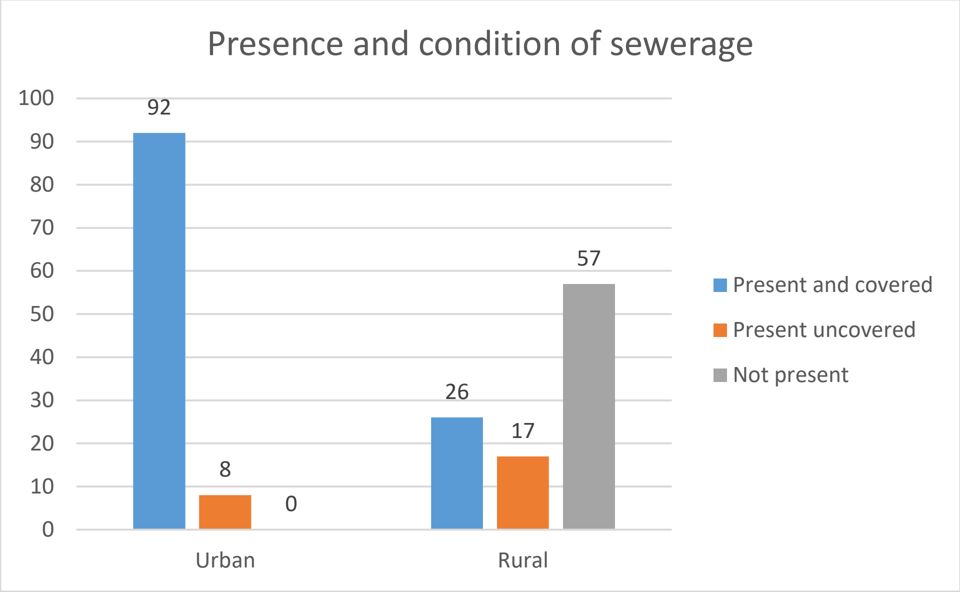


Figure 10 Sewerage

5.2 Physical vulnerability against earthquake

5.2.1 Number of stories

The number of stories is one of the most important indicators for assessing the physical vulnerability of the buildings to an earthquake. As the number of stories increases, physical vulnerability also increases because loading increases with the number of stories, and it is difficult to evacuate during an earthquake if the number of stories increases. During the field survey conducted in 2021, it is found that 61% of the houses have two stories while 11% of the houses have three or more stories. On the other hand, 40% of the houses in rural areas have only one storey whereas 57% of the houses have two stories.

Table 13 Number of stories

Number of stories	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value

1	79	28.2	56	40	0.002
2	169	60.4	80	57.1	
3 or more	32	11.4	4	2.9	

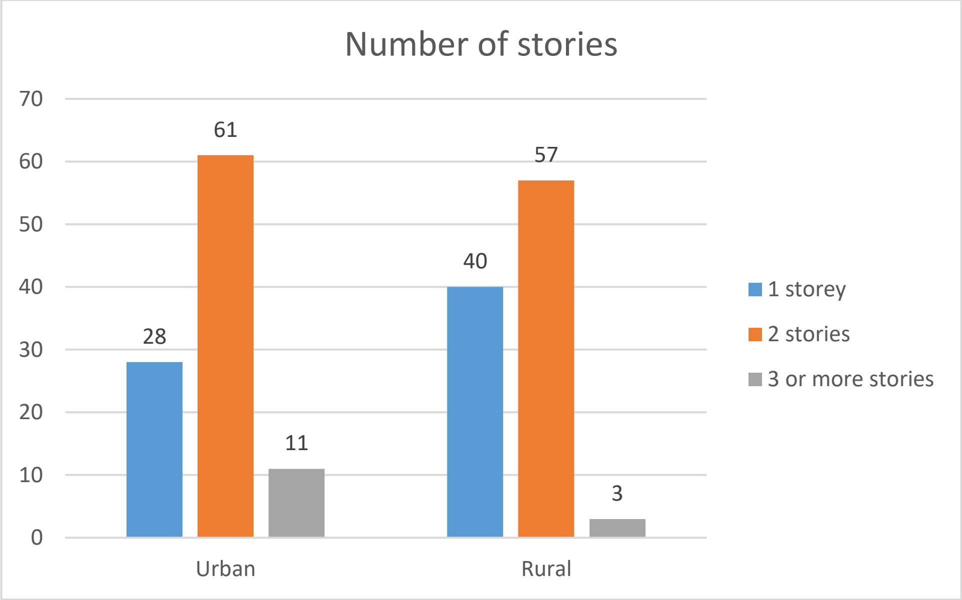


Figure 11 Number of stories

5.2.2 Construction type of building

The construction type of the house is very important because different types of construction behave differently during an earthquake. Unreinforced stone masonry is very weak against earthquakes, while RC frame structure with infill walls is comparatively way stronger against earthquakes. Field survey shows that 69% of the houses in the urban areas have RC frame structures with infill walls, while very few houses have other types of structures, as shown in the table below. On the other hand, 60% of the houses in rural areas have a wooden structure with stone masonry, and only 17% of the houses have RC frame structure.

Table 14 Construction type of building

Construction type of building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Unreinforced stone masonry	0	0	20	14.3	0.000
Wooden structure with stone walls	4	1.4	84	60	
Unreinforced brick masonry	83	29.6	12	8.6	
RC frame with infill walls	193	68.9	24	17.1	

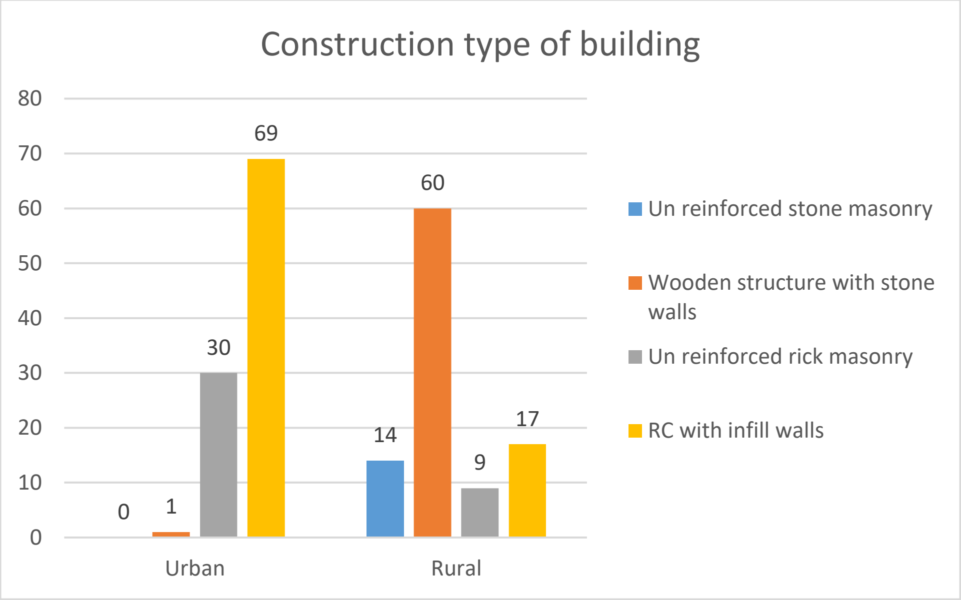


Figure 12 Construction type

5.2.3 Plan irregularity

Irregularity in the plan can increase the vulnerability of the building against earthquakes. Field survey shows that 56% of the houses in urban areas have regular in shape while only 9% of the buildings are irregular in plan. On the other hand, only 4% of the houses in rural areas have plan irregularity whereas most of the buildings are regular in shape.

Table 15 Plan irregularity

Plan irregularity	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Regular	158	56.4	115	82.1	0.000
Slightly irregular	97	34.6	20	14.3	
Irregular	25	8.9	5	3.6	

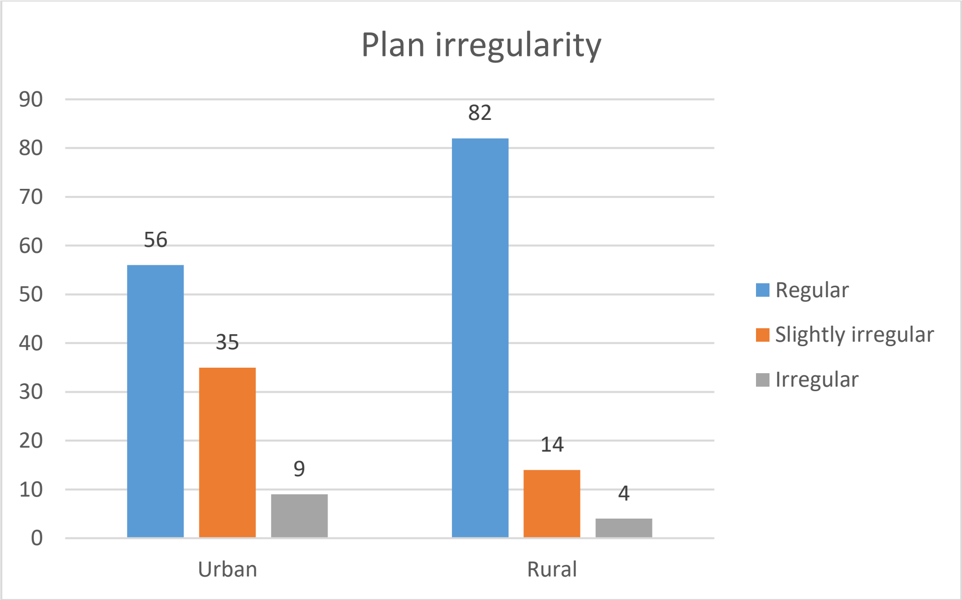


Figure 13 Plan irregularity

5.2.4 Vertical irregularity

Like plan irregularity, vertical irregularity can also contribute to increasing the vulnerability of the building. As the result of the field survey, it is found that only 12% of the houses in urban areas have vertical irregularity, whereas, in rural areas, no house is completely irregular in vertical plan.

Table 16 Vertical irregularity

Vertical irregularity	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Regular	168	60	113	80.7	0.000
Slightly irregular	78	27.9	27	19.3	
Irregular	34	12.1	0	0	

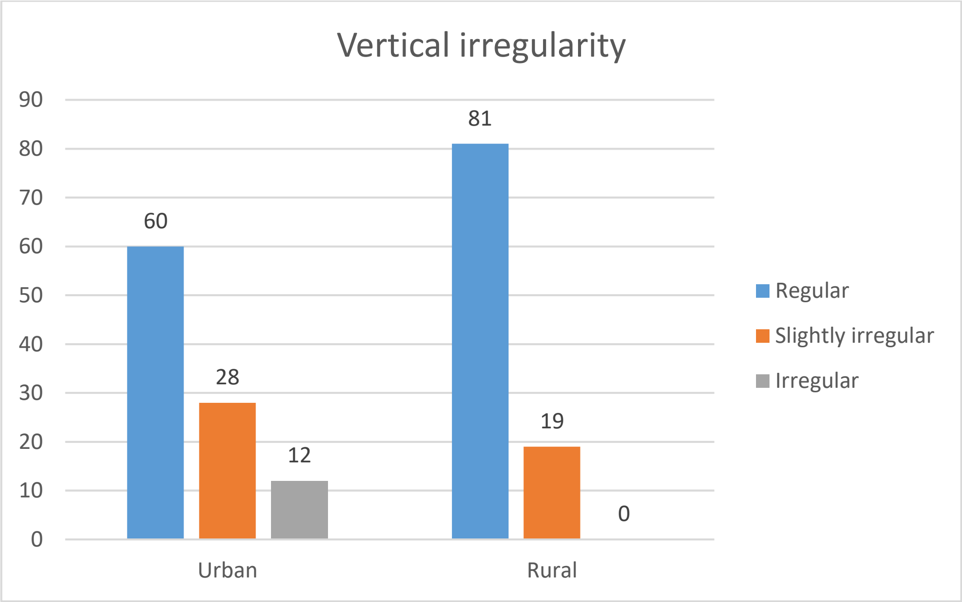


Figure 14 Vertical irregularity

5.2.5 Building apparent construction quality

The construction quality of the building is also very important in case of an earthquake. The buildings with poor connections between the walls and structural elements perform less effectively as compared to those with good connections between the walls and structural elements. A field survey reveals that 47% of the houses in the urban areas have a good quality of construction and have good connections between walls and structural elements. On the other hand, only 17% of the houses in the rural areas have good construction quality, while 74% of the houses have medium apparent construction quality.

Table 17 Building apparent construction quality

Building apparent construction quality	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Good	132	47.1	24	17.1	0.000
Medium	132	47.1	104	74.3	
Poor	16	5.7	12	8.6	

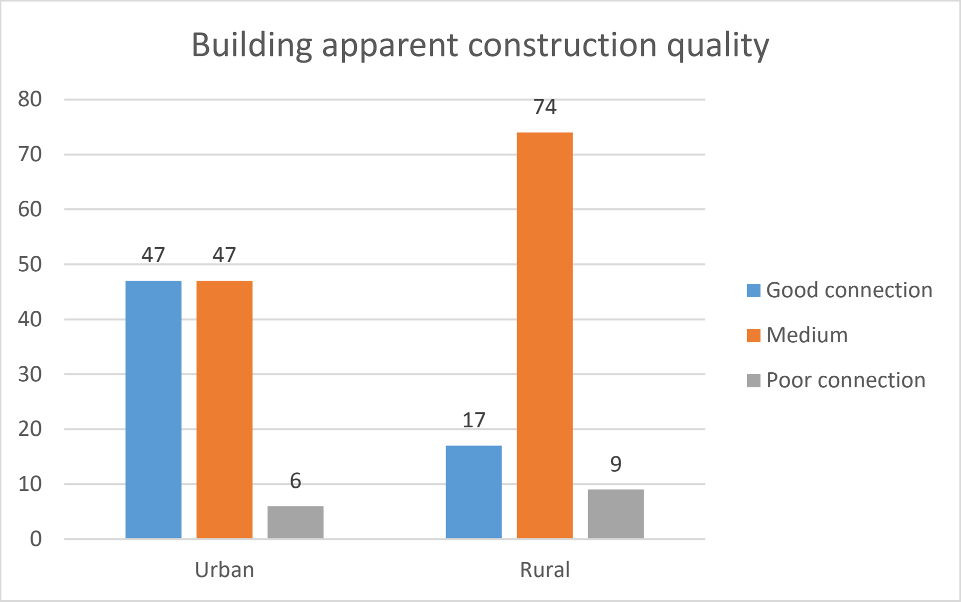


Figure 15 Construction quality

5.2.6 Apparent material quality

The quality of the material used in the construction can also play an important role in the behavior of the building in case of an earthquake. Data obtained during the field survey shows that 39% of the houses in urban areas have a good quality of material used in their construction, while 60% of the houses were constructed using average quality material. On the other hand, 24% of the houses in rural areas were built using good quality material.

Table 18 Apparent material quality

Apparent material quality	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Poor	4	1.4	8	5.7	0.000
Average	168	60	104	74.3	
Good	108	38.6	28	20	

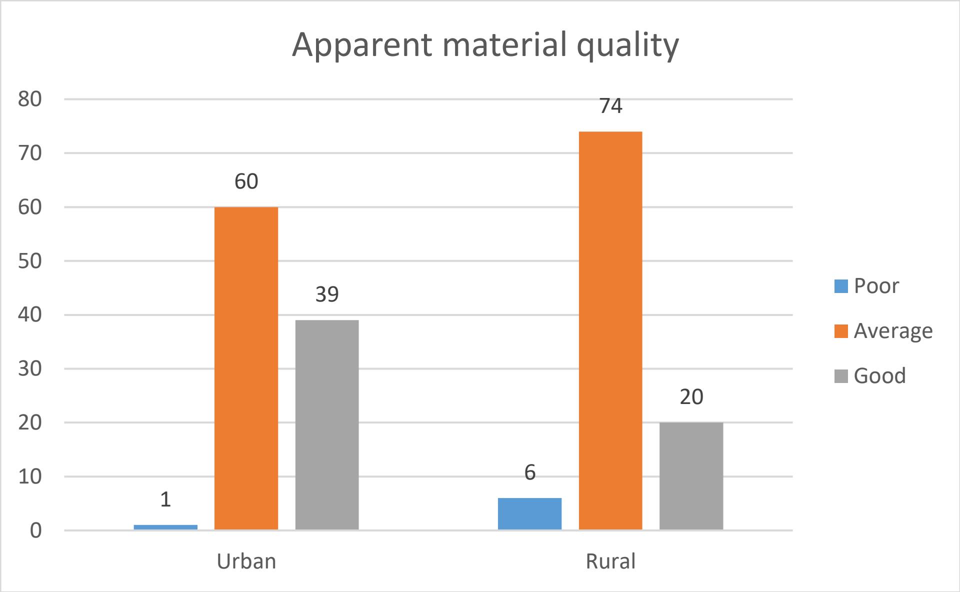


Figure 16 Material quality

5.2.7 Parapet

The presence and condition of the parapet in case of an earthquake are very important because the parapet may fall during an earthquake and cause live damage. A field survey shows that 51% of houses in the urban areas have properly anchored parapet walls, while in 33% of the houses, there is no parapet. On the other hand, there is no parapet on any house in the rural areas.

Table 19 Presence and condition of the parapet

Presence and condition of the parapet	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Unanchored	4	1.4	0	0	
Anchored	144	51.4	0	0	

Improperly anchored	40	14.3	0	0	0.000
Not present	92	32.9	140	100	

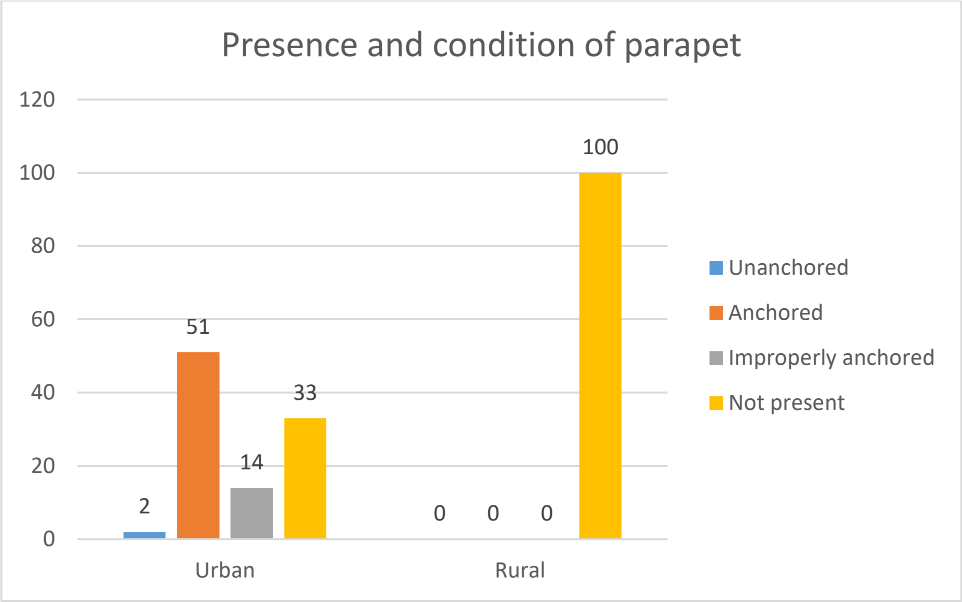


Figure 17 Parapet

5.2.8 Minimum gap with adjacent building

The gap between the buildings is very necessary to avoid the extra loading on the buildings in case of an earthquake. Data shows that 73% of the houses have less than 100 mm gap with the adjacent buildings, whereas, in rural areas, 91% of the houses have more than 100 mm gap with adjacent buildings.

Table 20 Gap with adjacent building

The minimum gap with adjacent building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
<100 mm per story	204	72.9	12	8.6	0.000
Otherwise	76	27.1	128	91.4	

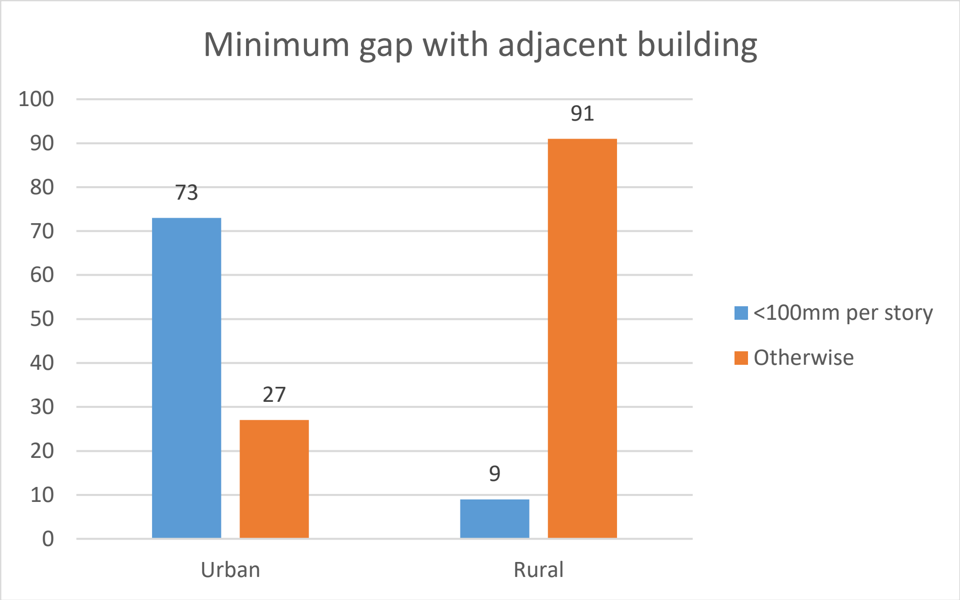


Figure 18 Minimum gap with adjacent buildings

5.2.9 Maintenance condition

The maintenance condition of a house is also an important factor to consider when assessing vulnerability. Data obtained during the field survey shows that 9% of the houses in urban areas have poor maintenance conditions while 45% of the houses are in good condition. On the other hand, 11% of the houses in rural areas have poor maintenance conditions while 26% of the houses are in good condition.

Table 21 Maintenance condition

Maintenance condition	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Poor	24	8.6	16	11.4	0.000
Average	128	45.7	88	62.9	
Good	128	45.7	36	25.7	

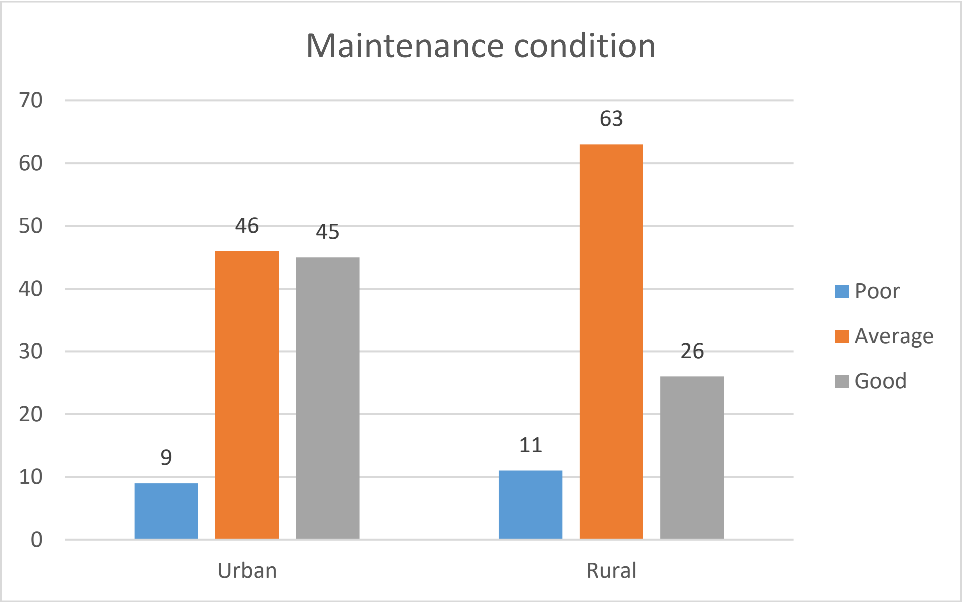


Figure 19 Maintenance condition

5.2.10 Maximum wall span in the building

The maximum wall span of a building is also important when dealing with earthquake hazards. As the result of a field survey, it is found that 29% of the houses in urban areas have a wall span of 13 feet or less, while 61% have a a wall span between 13 feet and 20 feet. On the other hand, 69% of the houses in rural areas have a wall span of 13 feet or less, and 31% of the houses have a maximum wall span of 13 feet to 20 feet.

Table 22 Maximum wall span

Maximum wall span in the building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
13 feet or less	80	28.6	96	68.6	0.000
13 to 20 feet	172	61.4	44	31.4	
More than 20 feet	28	10	0	0	

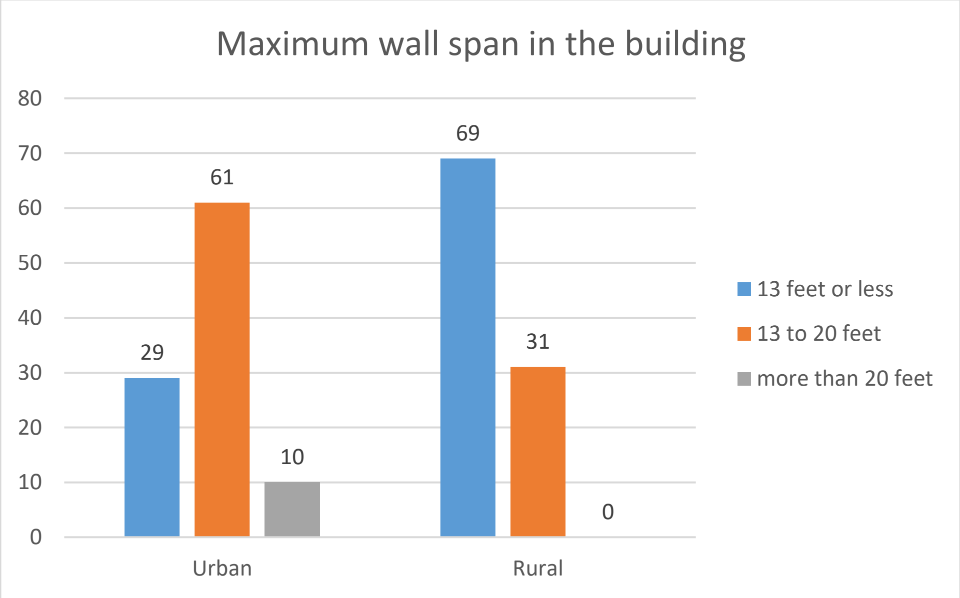


Figure 20 Maximum wall span

5.2.11 Alterations in building

Whenever there is an alteration in the existing building, there are fair chances that the vulnerability of that building will increase because the bonding between new and old construction is weak. During field survey 2021, it is found that 9% of the houses in urban areas have major alterations and 17% have minor ones. In rural areas, only 6% of the houses have minor alterations.

Table 23 Alterations in building

Alterations in building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Major	24	8.6	0	0	0.000
Minor	48	17.1	8	5.7	
None	208	74.3	132	94.3	

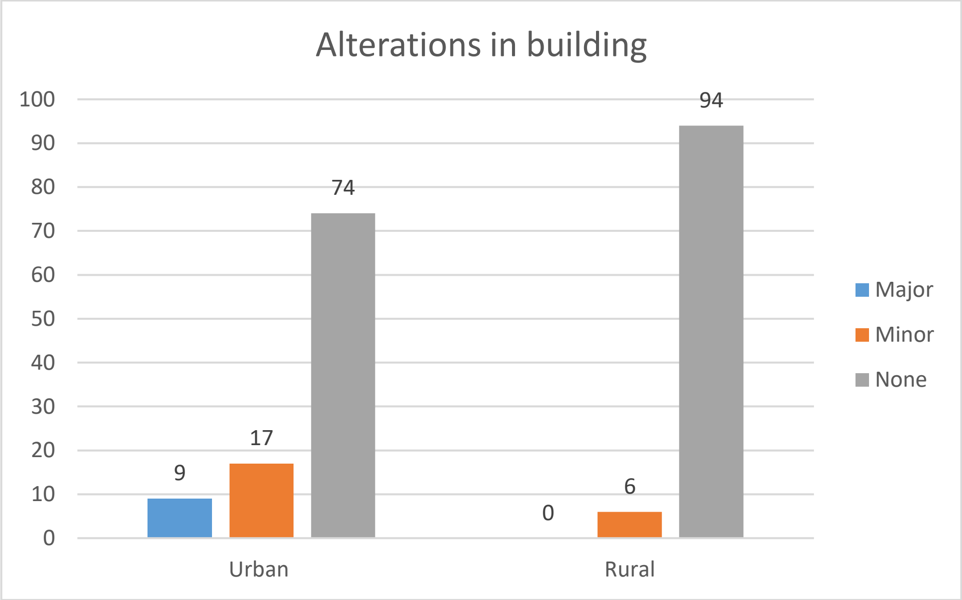


Figure 21 Alterations

5.2.12 Floating columns

The floating column is a relatively weak spot in the building in case of an earthquake. These are the ones that are not attached to the beams at desired positions. These have either greater heights than a storey, or they are resting directly on the slab or wall without the support of a beam. Data shows that 23% of the houses in urban areas have floating columns in them, while only 11% of the houses in rural areas have floating columns.

Table 24 Presence of floating columns

Presence of floating columns	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Yes	64	22.9	16	11.4	0.003
No	216	77.1	124	88.6	

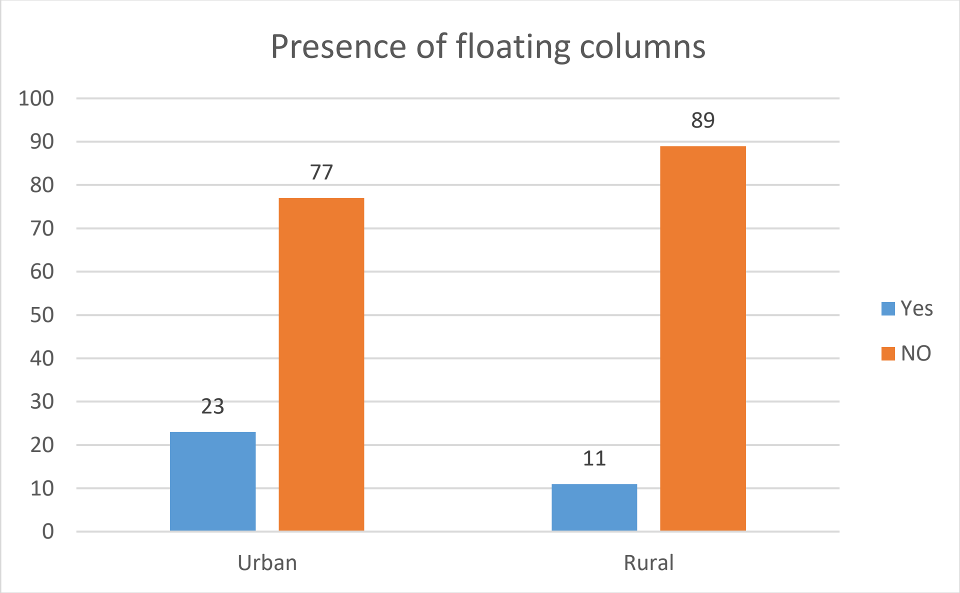


Figure 22 Floating columns

5.2.13 Previous structural damage

If a building is already damaged in a previous earthquake or due to any other reason, its vulnerability increases. Data shows that 24% of the buildings in urban areas are slightly damaged, while 40% of the buildings are slightly damaged in rural areas.

Table 25 Previous structural damage

Previous structural damage	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
No visible damage	212	75.7	84	60	0.001
Slight damage	68	24.3	56	40	

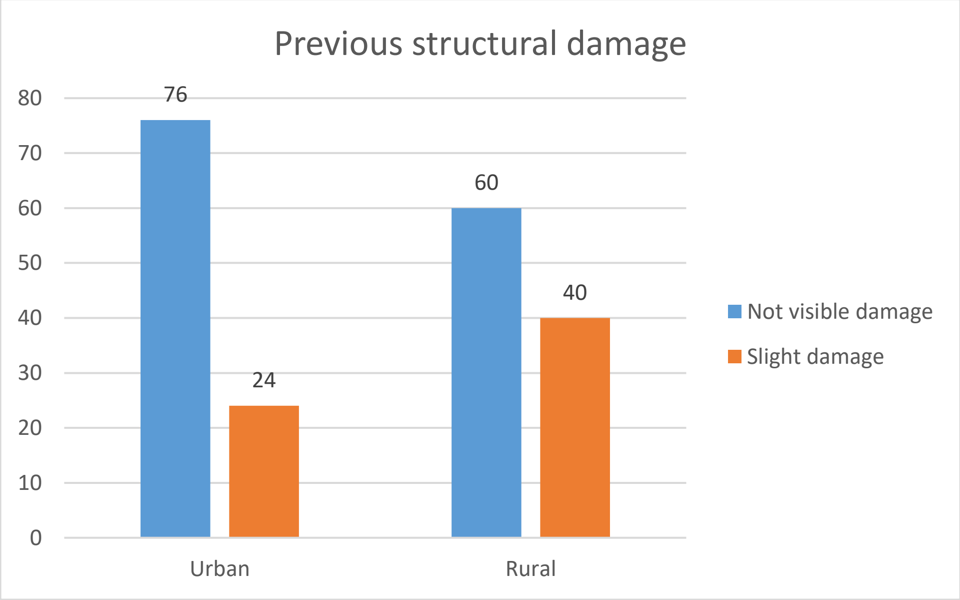


Figure 23 Previous structural damage

5.2.14 Type of soil

The type of soil on which the building is constructed is very important when assessing the physical vulnerability to earthquakes. The buildings on hard soil are more stable than the buildings on soft soil. The data from the field survey shows that 23% of the houses in urban areas are constructed on hard soil, whereas 14% of the houses are constructed on soft soil. Similarly, the percentages of houses on hard and soft soil in rural areas are also the same as in urban areas.

Table 26 Type of soil

Type of soil	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Hard	64	22.9	32	22.9	1.000
Medium	176	62.9	88	62.9	
Soft	40	14.3	20	14.3	

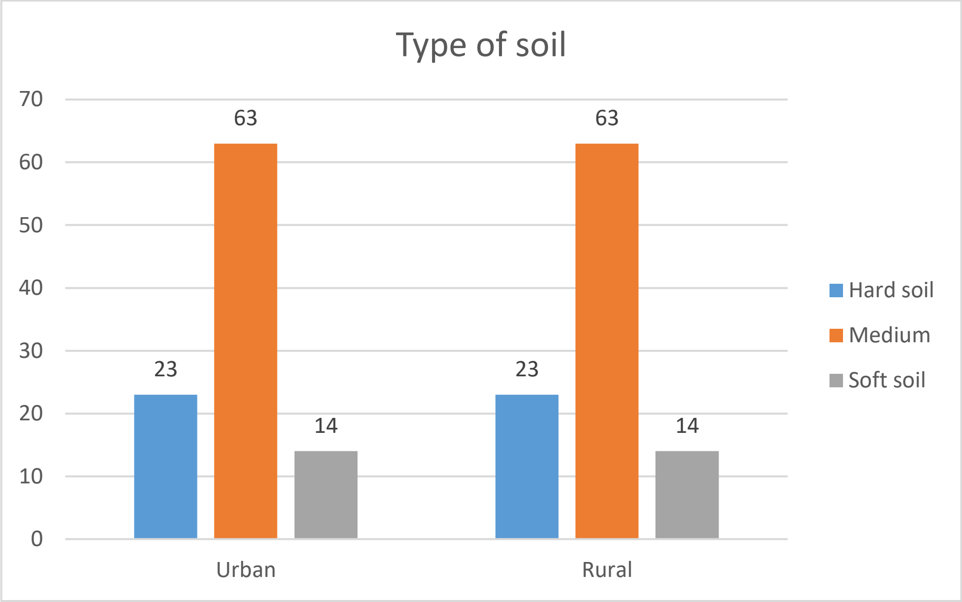


Figure 24 Type of soil

5.2.15 Type of wall

The type of wall is also an important contributor to the strength of building. The field survey conducted in 2021 shows that no building in the urban area has stone walls, whereas 44% of the buildings have brick walls. The remaining houses have block walls. On the other hand, 46% of the houses in rural areas have stone walls, 49% of the houses have block walls, and only 5% of the houses have brick walls.

Table 27 Type of wall

Type of wall	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Stone	0	0	64	45.7	0.000
Block	156	55.7	68	48.6	
Brick	124	44.3	8	5.7	

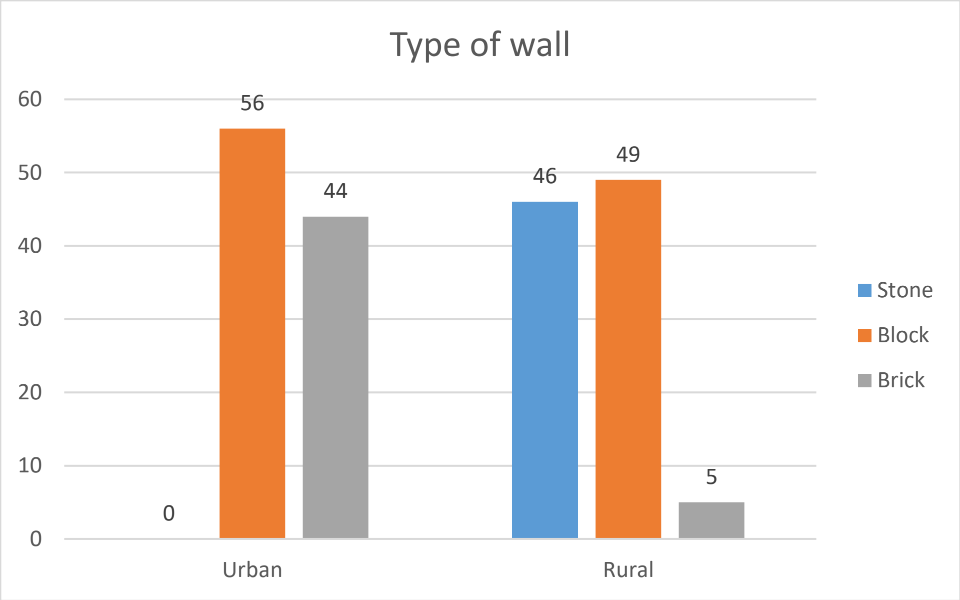


Figure 25 Type of wall

5.2.16 Type of mortar

Field survey shows that all the houses in the urban areas have cement mortar used in their construction, while on the other hand, 11% of the houses in rural areas were constructed using mud as mortar.

Table 28 Type of mortar

Type of mortar	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Mud	0	0	16	11.4	0.000
Cement	280	100	124	88.6	

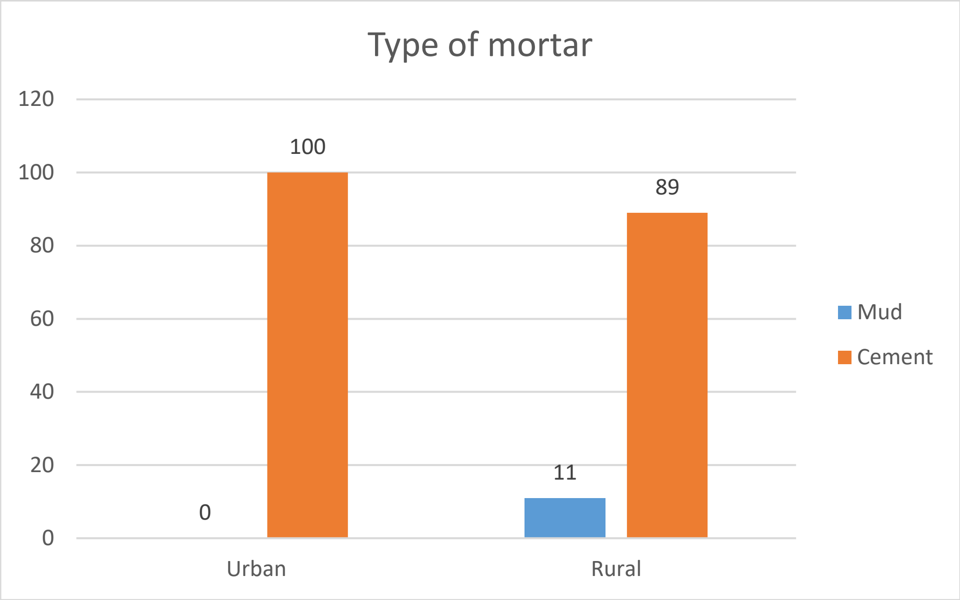


Figure 26 Type of mortar

5.2.17 Dampness

Dampness in the building increases vulnerability by lowering the strength of the affected structural elements. Data shows that 11% of the buildings in the urban areas have dampness, while 6% of the houses in rural areas are affected by dampness.

Table 29 Degree of dampness

Degree of dampness	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Damped	32	11.4	8	5.7	0.013
Slightly damped	120	42.9	48	34.3	
No dampness	128	45.7	84	60	

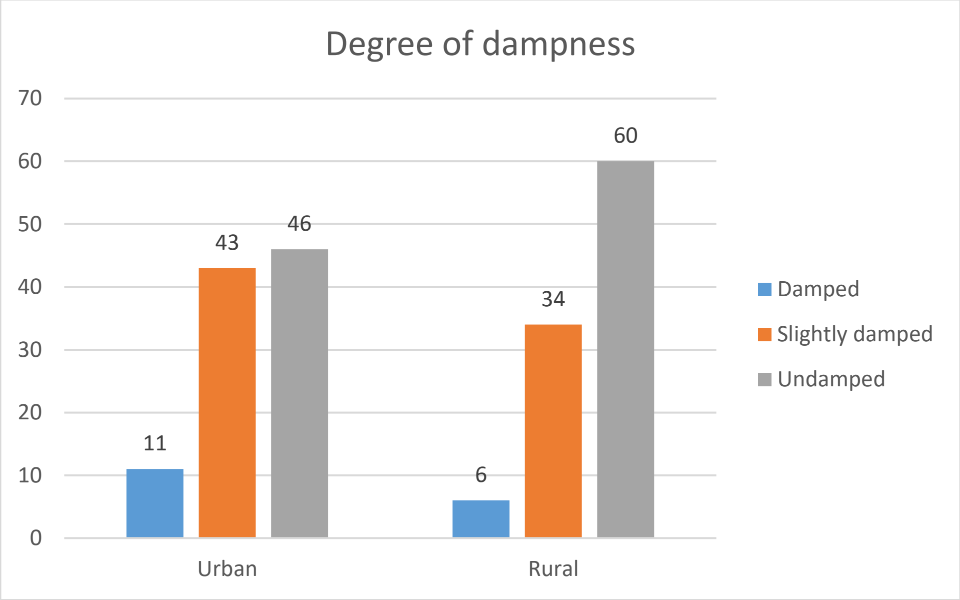


Figure 27 Dampness

5.2.18 Plan approval

Approval of the plan from the concerned authority is very necessary before construction because if there is any deficiency in the plan, it can be pointed out by the professionals, and then it can be fixed. During the field survey, it was found that only 21% of the houses in urban areas have approved their plans by concerned authorities while in rural areas, no house was constructed on the approved plan.

Table 30 Plan approval

Plan approval	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Yes	60	21.4	0	0	0.000
No	220	78.6	140	100	

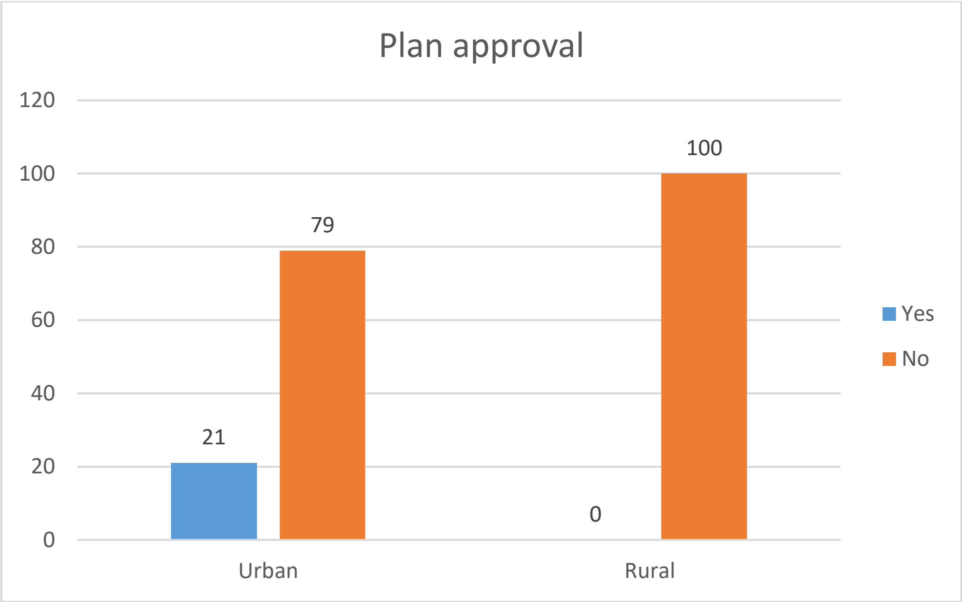


Figure 28 Plan approval

5.2.19 Heavy mass at the top

Whenever there is heavy mass at the top of a building in the form of any water tank, storage room, etc., it may be dangerous during the occurrence of an earthquake. After the field survey, data reveals that in urban areas, 27% of the buildings have heavy mass at the top, whereas in rural areas, only 14% of the houses have heavy mass at the top, as shown in the table below.

Table 31 Heavy mass at the top

Heavy mass at the top	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Yes	76	27.1	20	14.3	0.002
No	204	72.9	120	85.7	

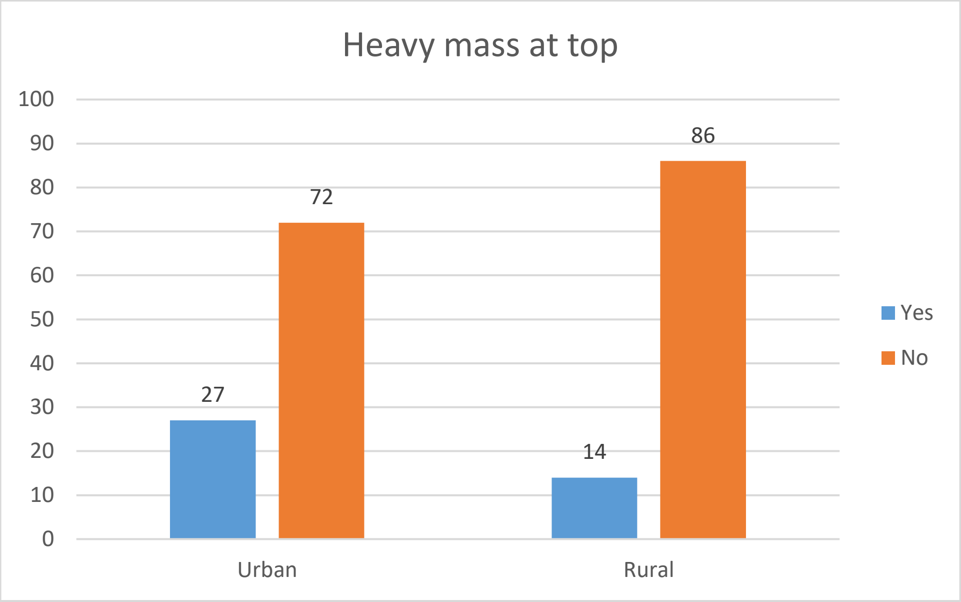


Figure 29 Heavy mass at top

5.2.20 Type of roof

The type of roof has an important role in case of building collapse due to an earthquake. RCC slab is very dangerous if it falls during an earthquake and can cause serious threats to human lives. Compared to it, the asbestos sheet roof supported with wooden supports is relatively less dangerous. The asbestos sheet roof supported with iron supports is even safer than the roof with wooden supports. Data shows that the houses in urban areas have RCC slabs in 90% of the cases, wooden supported asbestos sheet roofs in 9%, and only 1% of the houses have supported an iron roof. Whereas in rural areas, no house has a slab roof, 69% of the houses have wooden support roofs, and 31% of the houses have iron support asbestos sheet roofs.

Table 32 Type of roof

Type of roof	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
RCC slab	252	90	0	0	0.000
Asbestos sheets with wooden support	24	8.6	95	68.6	
Asbestos sheets with iron support	4	1.4	44	31.4	

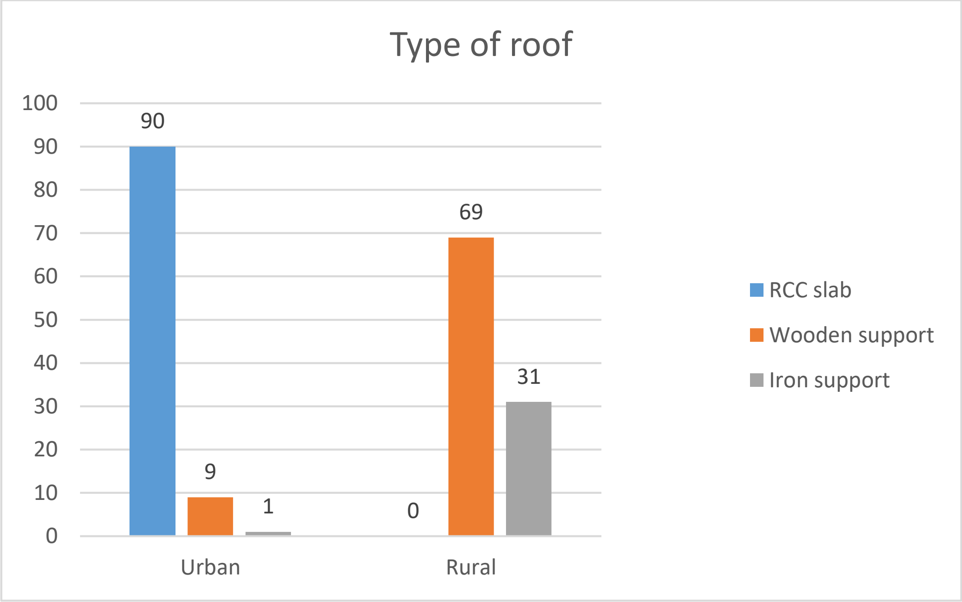


Figure 30 Type of roof

5.2.21 Building location

During an earthquake, the location of the building w.r.t other buildings is also very crucial because the vibrations of one building may adversely affect the other adjacent buildings. The results of the field survey show that in urban areas, 54% of the buildings are internally located with buildings attached to them on all three sides, 23% of the houses are at the corner with buildings attached on two sides of them, 16% of the buildings are at the end with one side of them attached to the other building and only &5 of the houses are completely isolated. On the other hand, in rural areas, 75% of the houses are isolated, and 11% of the houses are internally located.

Table 33 Building location

Building location w.r.t other building	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Internal	152	54.3	16	11.4	0.000
Corner	64	22.9	4	2.9	
End	44	15.7	16	11.4	
Isolated	20	7.1	104	74.3	

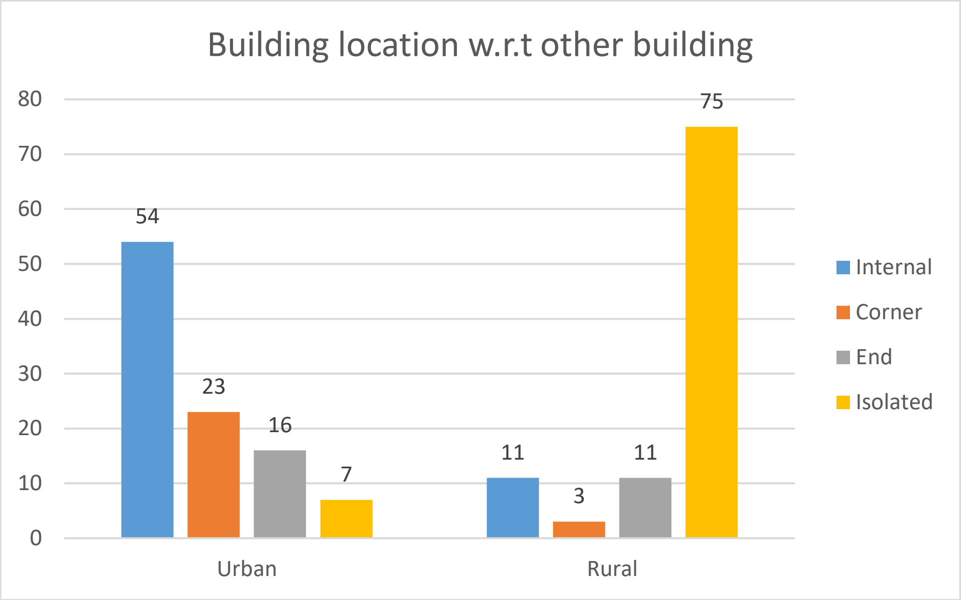


Figure 31 Building location

5.2.22 Type of construction

Whenever a building is constructed, it is very important who is conducting and supervising the construction process. There is a lot of difference in the quality of construction supervised by an engineer compared to that of a local contractor or a layman. Thus, it is an important indicator in assessing the physical vulnerability of buildings against any hazard, especially earthquake. During the field survey conducted in 2021, it was found that in the construction of 21% of the houses in urban areas, there is the involvement of engineers, whereas local contractors constructed 69% of the houses. On the other hand, no house in rural areas is constructed under the supervision of an engineer, while 40% of the house were constructed under the self-supervision of the owners.

Table 34 Type of construction

Type of construction	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Engineered	60	21.4	0	0	0.000
Local contractor	192	68.6	84	60	
Self-supervision	28	10	56	40	

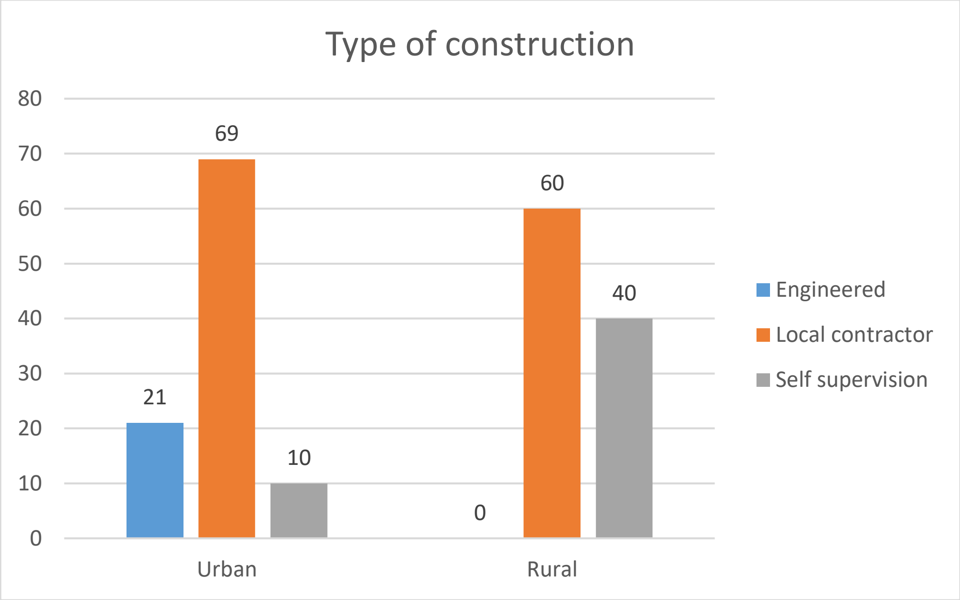


Figure 32 Type of construction

5.2.23 Maximum overhang length

Overhang length can be very dangerous if it falls during the earthquake, thus it is an important physical vulnerability indicator. Field survey shows that in urban areas, only 7% of the houses have maximum overhang length greater than 1.5 meter whereas in rural areas, only 3% of the houses have maximum overhang length greater than 1.5 meter.

Table 35 Maximum overhang length

Maximum overhang length	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Less than 1.5 m	260	92.9	136	97.1	0.054
More than 1.5 m	20	7.1	4	2.9	

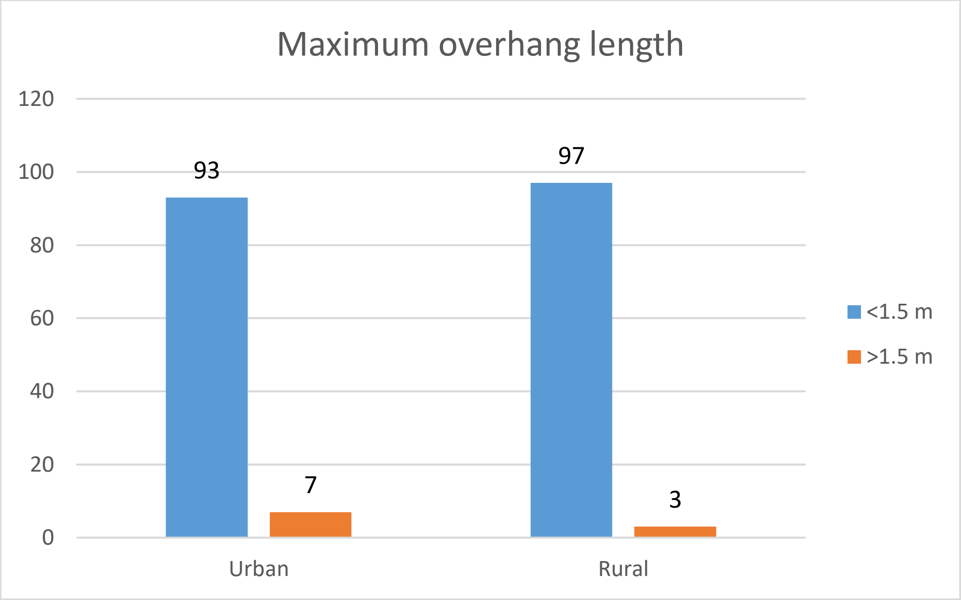


Figure 33 Overhang length

5.3 Social vulnerability profile

5.3.1 Household income

Household income shows the affordability and financial status of the households. A field survey conducted in 2021 shows that in urban areas, only 3% of the households earn below PKR 25000, whereas 37% earn more than PKR 100000 per month. On the other hand, 12% of the households in rural areas earn below PKR 25000 per month, whereas only 9% earn more than PKR 100000 a month. A major portion of the households in rural areas have earnings in between these two amounts.

Table 36 Household income

Household income	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Less than 25000	8	2.9	18	12.9	0.000
25000 to 50000	36	12.9	54	38.6	
50000 to 1 lac	132	47.1	56	40	
More than 1 lac	104	37.1	12	8.6	

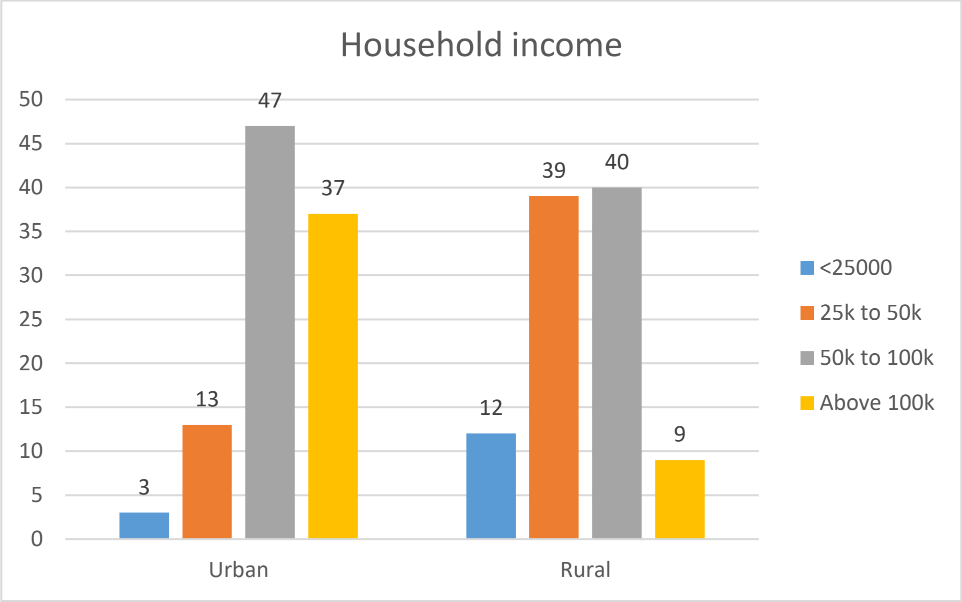


Figure 34 Household income

5.3.2 Household size

Results show that 74% of households in rural areas have 5 to 9 house members, whereas 53% of the houses in urban areas have that many members. 21% of households in the urban areas have more than 10 members in their family, while in the rural areas, only 6% of households have more than 10 family members.

Table 37 Household size

Household size	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Less than 5	72	25.7	28	20	0.000
5 to 9	148	52.9	104	74.3	
10 or more	60	21.4	8	5.7	

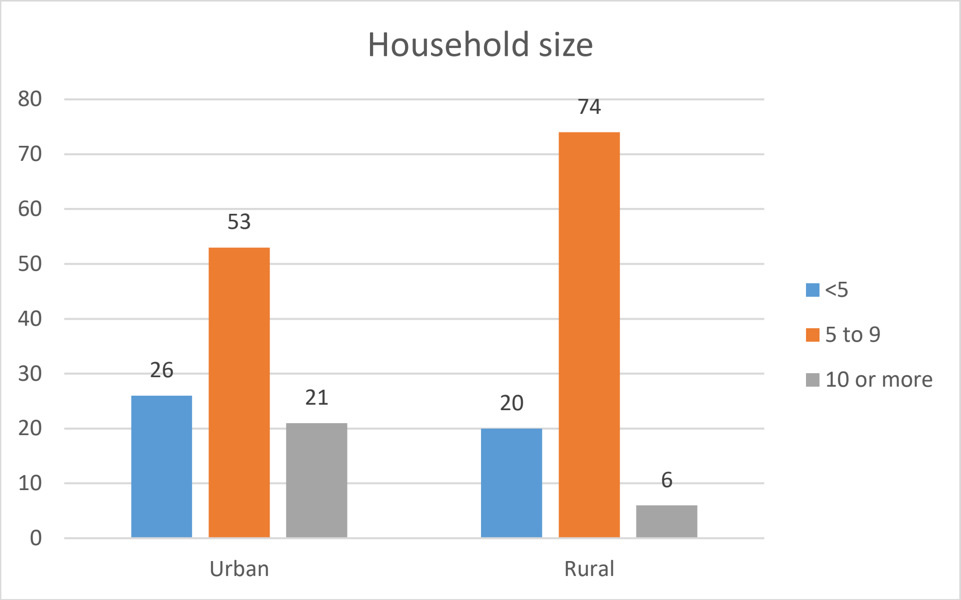


Figure 35 Household size

5.3.3 House ownership

The data shows that in urban areas, 58% of the people have their own houses, whereas in rural areas, 99% of the people have their own houses.

Table 38 House ownership

House ownership	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Owned	162	57.9	138	98.6	0.000
Rented	118	42.1	2	1.4	

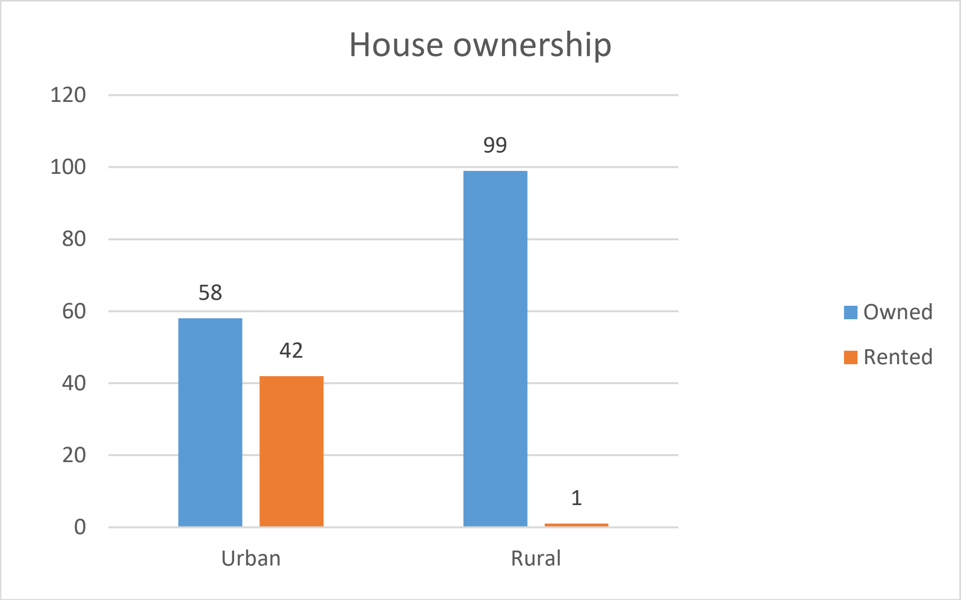


Figure 36 House ownership

5.3.4 Male to female ratio

During the field survey, it is found that in 21% of the households, the male to female ratio is smaller than 1 while in 20% of the houses, it is greater than 1. On the other hand, data shows that in rural areas, there are more women than men in 35% of the houses, while in 14% of the households, there are more men than women.

Table 39 Male to female ratio

Male to female ratio	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
<1	60	21.4	48	34.3	0.014
1	164	58.6	72	51.4	
>1	56	20	20	14.3	

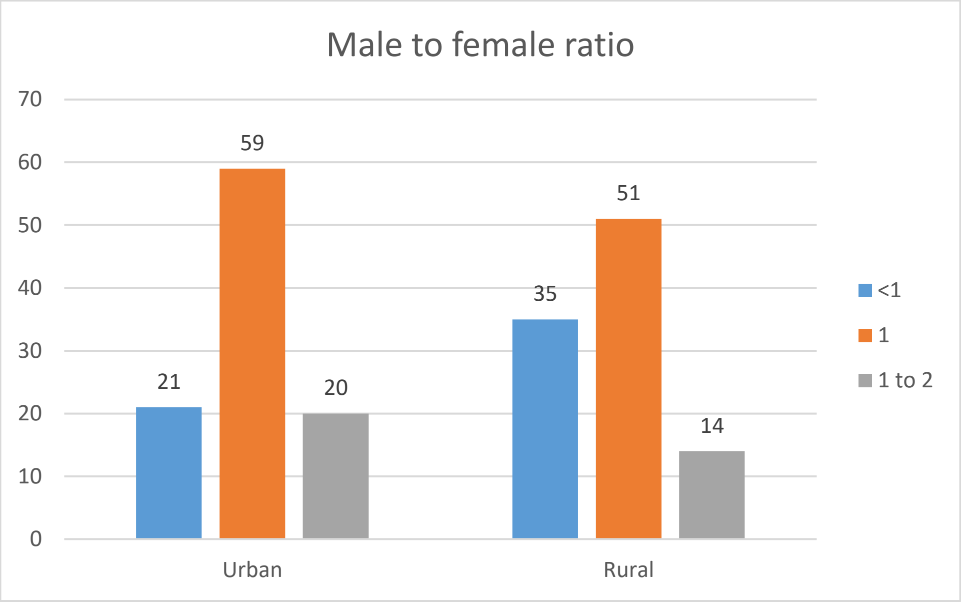


Figure 37 Male to female ratio

5.3.5 Number of disabled persons

The presence of disabled persons in any household increases its vulnerability. Data shows that in 99% of the houses in urban areas, there is no disabled person, while in rural areas, 98% of the houses have no disabled member.

Table 40 Number of disabled persons

Number of disabled persons	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
0	277	98.9	138	98.6	0.540
1 or more	3	1.1	2	1.4	

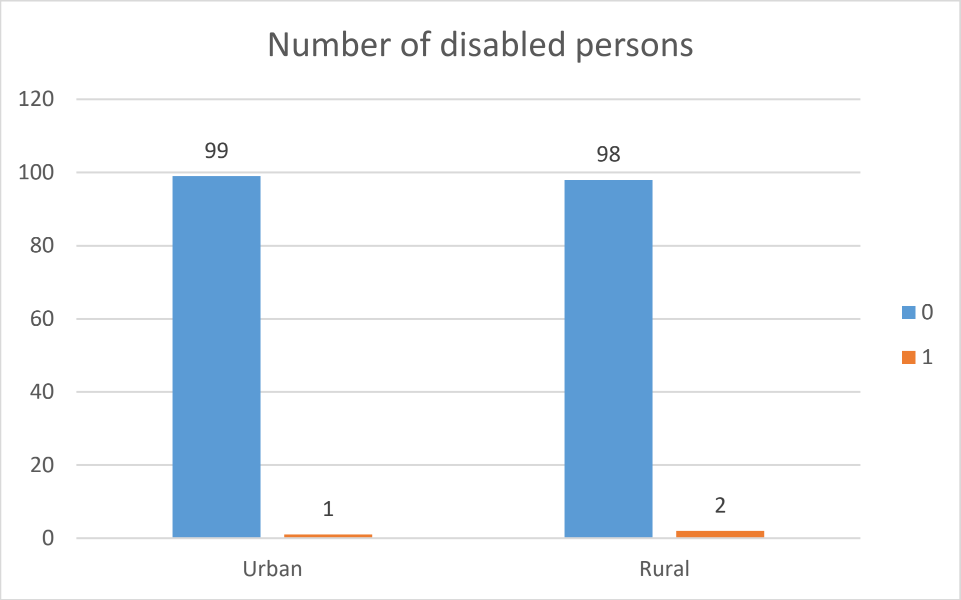


Figure 38 Disabled persons

5.3.6 Household members between 0 to 6 years

The presence of children in the house increases the vulnerability of the household to any hazards. Thus, it is an important indicator to be considered in assessing vulnerability against any hazard. During the field survey, it is found that in the urban areas, 57% of the houses have one child, whereas 20% have two children. In rural areas, 66% of the houses have at least one member in this age group.

Table 41 Number of people between 0 to 6 years

Number of people between 0 to 6 years	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
0	52	18.6	28	20	0.030
1	160	57.1	92	65.7	
2	56	20	20	14.3	

More than 2	12	4.3	0	0	

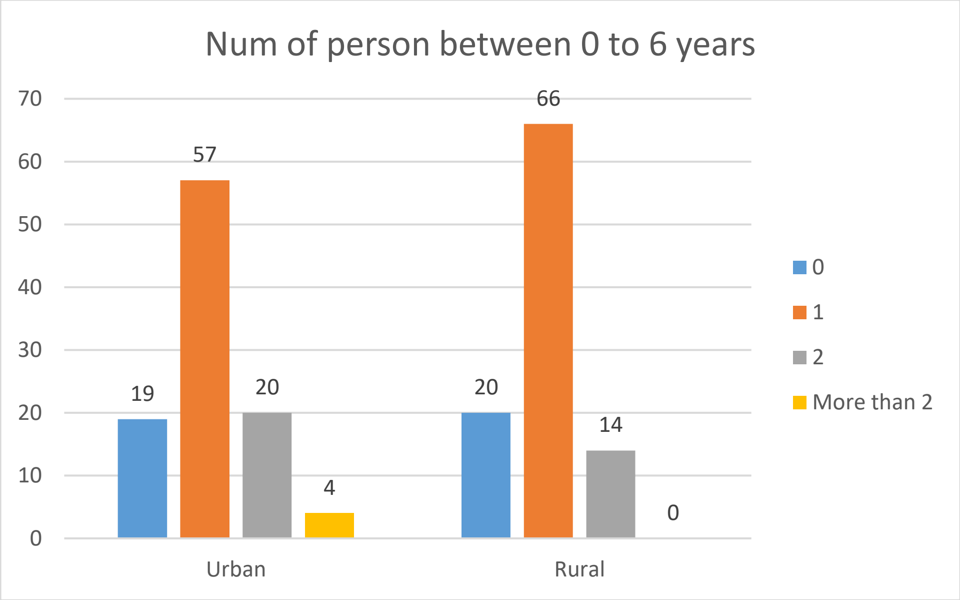


Figure 39 Number of children

5.3.7 Persons above 60 years

Having persons above 60 years of age in the household can increase the vulnerability against any hazard. Data collected during the field survey shows that in urban areas, 39% of the households have a person in this age group, while in rural areas, 57% of the households have a person in this age group.

Table 42 Persons above 60 years

Persons above 60 years	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
0	80	28.6	44	31.4	

1	108	38.6	80	57.1	0.000
2	88	31.4	16	11.4	
>2	4	1.4	0	0	

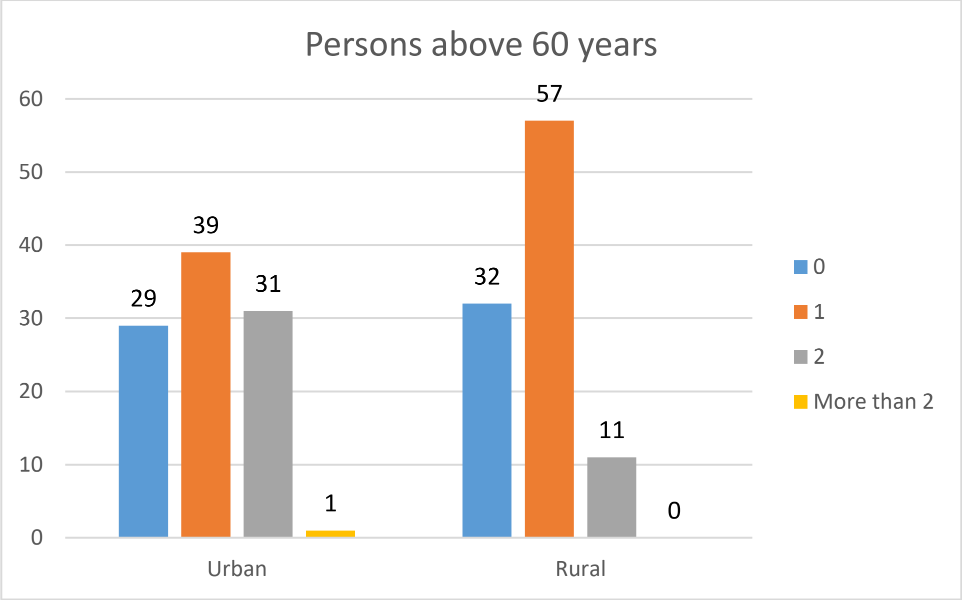


Figure 40 Old age persons

5.3.8 Household knowledge about disaster

Household knowledge about disasters is a crucial indicator as knowledge about possible hazards may contribute to reducing the vulnerability. Field data reveals that only 6% of the households in the urban areas have no knowledge about the hazards in the area, while 45% of the people know about earthquakes only, and 49% of the households have knowledge about both floods and earthquakes.

On the other hand, 45% of the households in the rural areas do not know about any disaster, and 46% of the households know aonly bout the earthquake hazard only.

Table 43 Household knowledge

Household knowledge about disaster	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
No knowledge	16	5.7	64	45.7	0.000
Only earthquake	128	45.7	64	45.7	
Both	136	48.6	12	8.6	

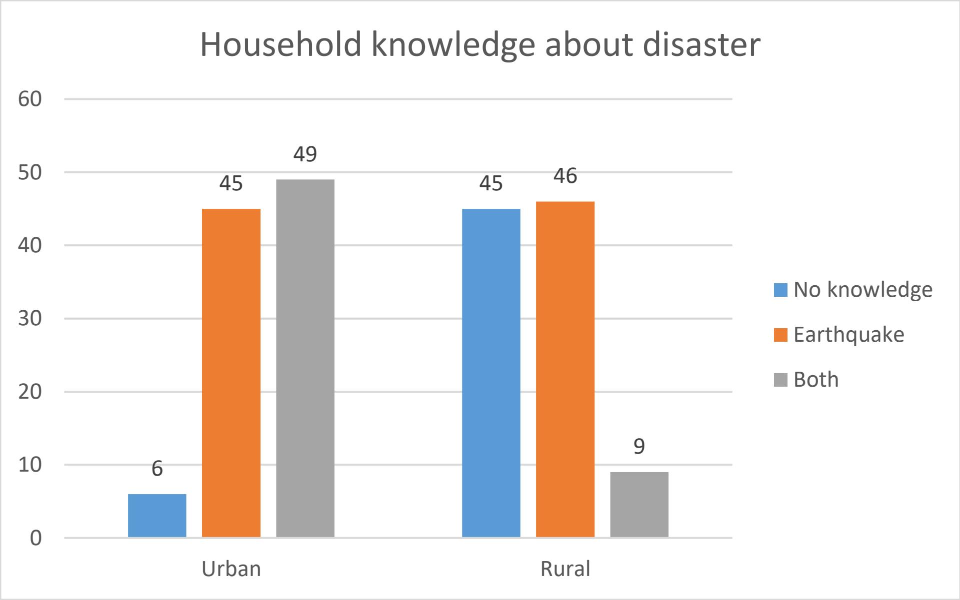


Figure 41 Knowledge about disaster

5.3.9 Quality of drinking water

The results of the field survey show that in urban areas, 23% of the households have filtered water for drinking, while 77% of the houses have a municipal water supply system. On the other hand, 82% of households in rural areas have access to ground water for drinking, while 18% of the houses have access to a municipal water supply system.

Table 44 Quality of drinking water

Quality of drinking water	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Filtered	64	22.9	0	0	0.000
Ground water	0	0	115	82.1	
Municipal water supply	216	77.1	25	17.9	

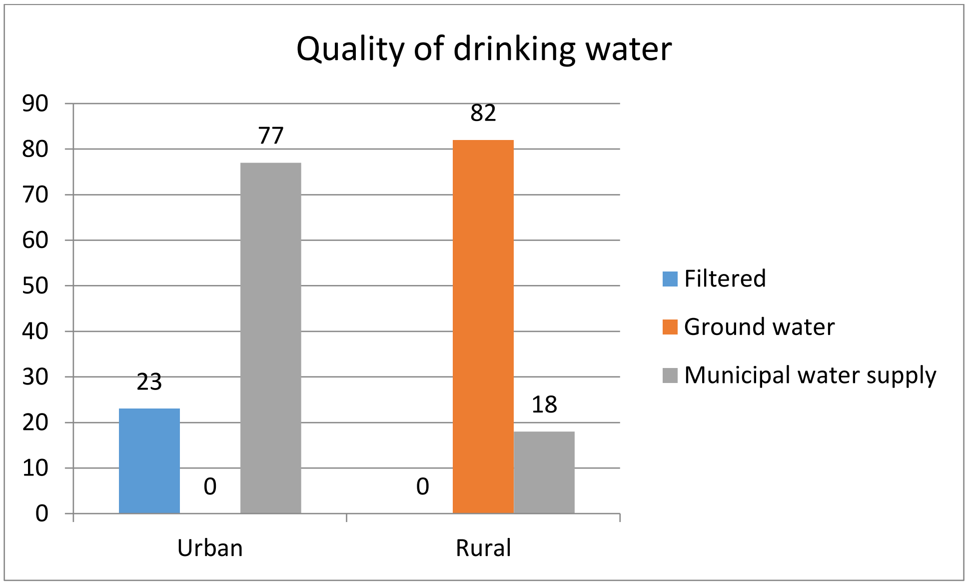


Figure 42 Quality of drinking water

5.3.10 Access to a medical facility

Access to a medical facility is a very important indicator of the social dimension of the vulnerability of any population against any disaster. As a result of a field survey, it is found that in urban areas, 75% of the households have easy access to a medical facility. In contrast, only 1% of households are at a large distance from a medical facility. On the contrary, no people living in rural areas have easy access to medical facilities, whereas 54% of households have medical facilities over large distances.

Table 45 Access to a medical facility

Access to a medical facility	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Easy	209	74.6	0	0	0.000
Medium	68	24.3	64	45.7	
Hard	3	1.1	76	54.3	

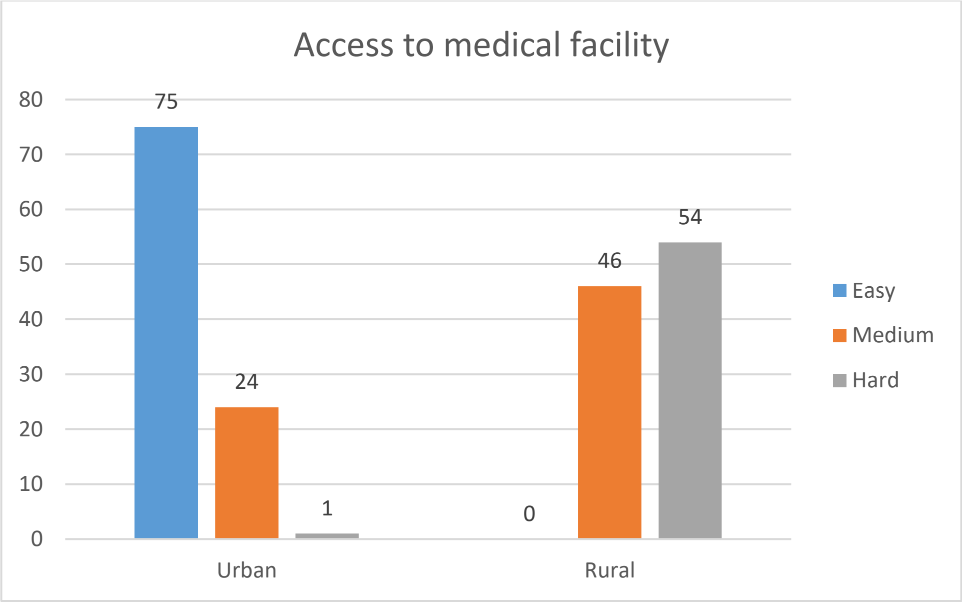


Figure 43 Access to medical facility

5.4 Total physical vulnerability

5.4.1 Against flood

This study shows that the houses in urban areas are more vulnerable to floods than those in rural areas. Data analysis shows that 20% of houses in the urban areas are very highly vulnerable to floods, while 11% of the houses in rural areas are very highly vulnerable to floods.

Table 46 TPV against flood

TPV against flood	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Low	52	18.6	30	21.4	0.180
Medium	93	33.2	47	33.6	
High	80	28.6	47	33.6	
Very high	55	19.6	16	11.4	

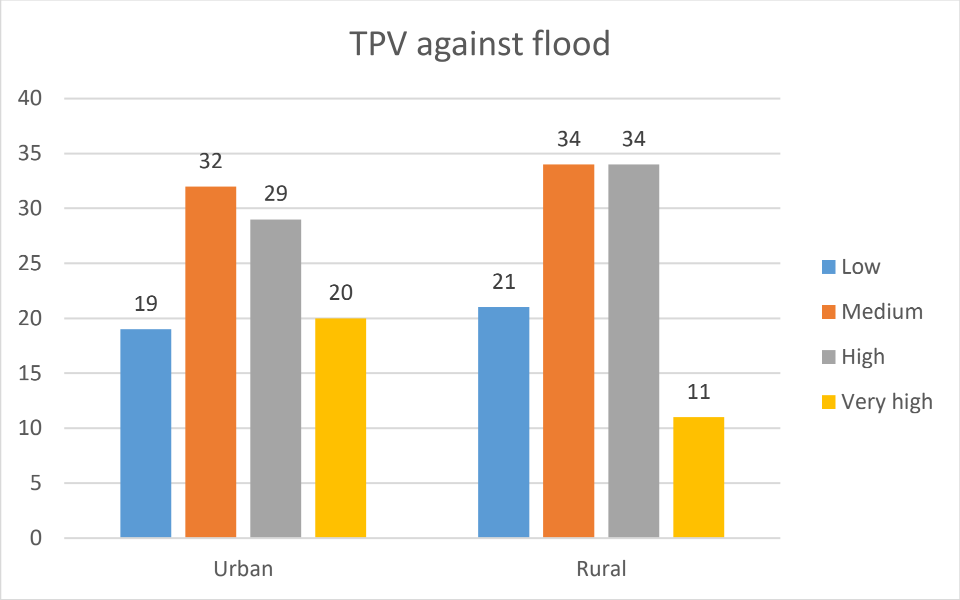


Figure 44 Physical vulnerability against flood

5.4.2 Against earthquake

The data shows that, similarly to floods, urban areas are more vulnerable to earthquakes than rural areas. Results reveal that 28% of the houses in urban areas are very high, while 46% of the houses are highly vulnerable to earthquakes. On the other hand, 30% of the houses are highly vulnerable.

Table 47 TPV against earthquake

TPV against earthquake	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Low	11	3.9	39	27.9	0.000
Medium	63	22.5	59	42.1	
High	129	46.1	41	29.3	

Very high	77	27.5	1	0.7	

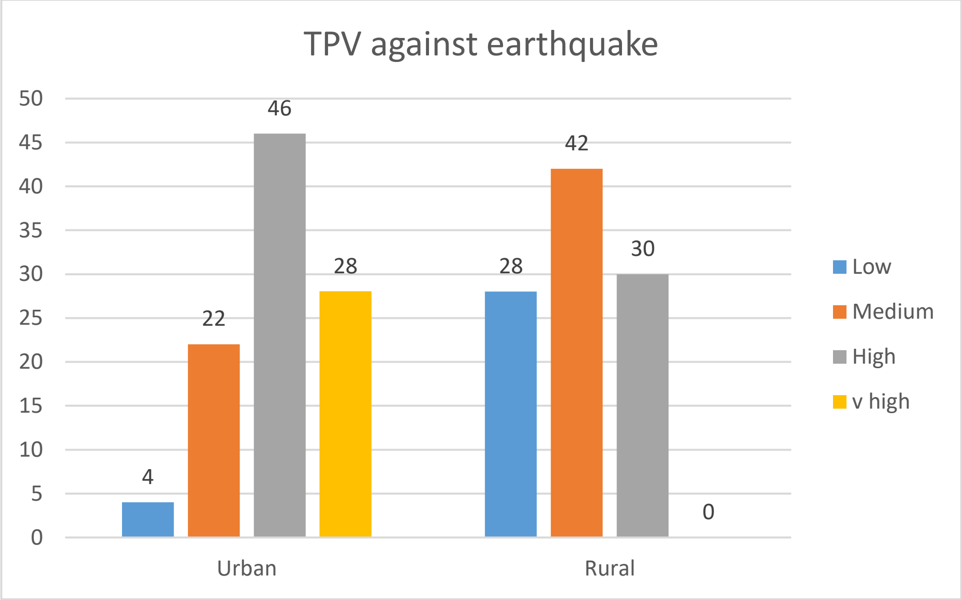


Figure 45 Physical vulnerability against earthquake

5.4.3 Total physical vulnerability

For total physical vulnerability, the values for both flood and earthquake were taken collectively. The results show that 33% of the houses in urban areas are highly vulnerable, while 4% fall under the category of very highly vulnerable. On the other hand, 18% of the houses in rural areas are highly vulnerable, while no house in the rural areas is very highly vulnerable.

Table 48 Total physical vulnerability

Total physical vulnerability	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Low	19	6.8	33	23.6	

Medium	158	56.4	81	57.9	0.000
High	93	33.2	26	18.6	
Very high	10	3.6	0	0	

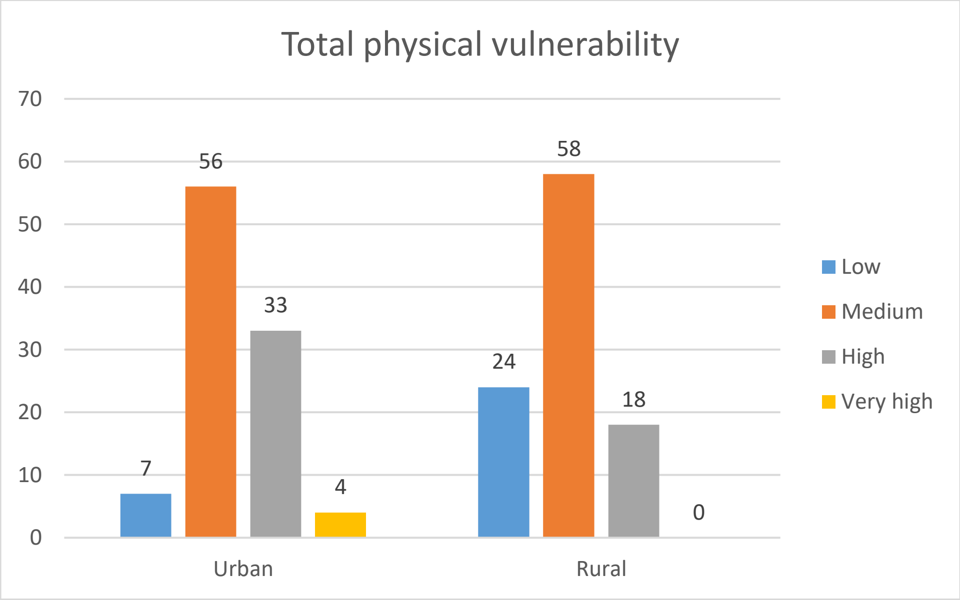


Figure 46 Total physical vulnerability

5.5 Social vulnerability

Contrary to the physical vulnerability, the urban areas are socially less vulnerable than the rural areas in the study area. Data shows that only 9% of the population is very highly vulnerable, and 42% of the people are highly vulnerable in urban areas. On the other hand, 20% of the people in rural areas are very highly vulnerable, and 56% of the people are highly vulnerable.

Table 49 Social vulnerability

Social vulnerability	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Low	43	15.4	16	11.4	0.000
Medium	96	34.3	18	12.9	
High	118	42.1	79	56.4	
Very high	23	8.2	27	19.3	

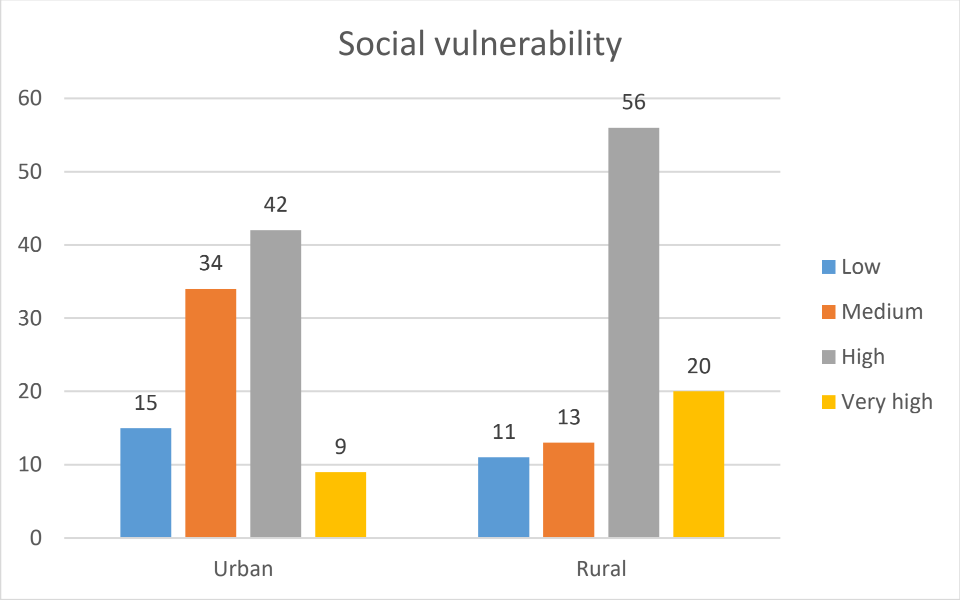


Figure 47 Total social vulnerability

5.6 Total vulnerability

For overall total vulnerability, the values of total physical and social vulnerability were added and compared for urban and rural areas. Results reveal that the total vulnerability of rural areas is higher than that of urban areas. It means that the social aspect of vulnerability contributes very much to the overall vulnerability of the rural regions and makes them more vulnerable compared to urban areas. According to the results, 53% of the houses in rural areas are highly vulnerable compared to 42% in urban areas.

Table 50 Total vulnerability

Total vulnerability	Urban (n=280)		Rural (n=140)		Chi-Square Test
	Freq	%	Freq	%	p-value
Low	6	2.1	11	7.9	0.000
Medium	125	44.6	36	25.7	
High	117	41.8	75	53.6	
Very high	32	11.4	18	12.9	

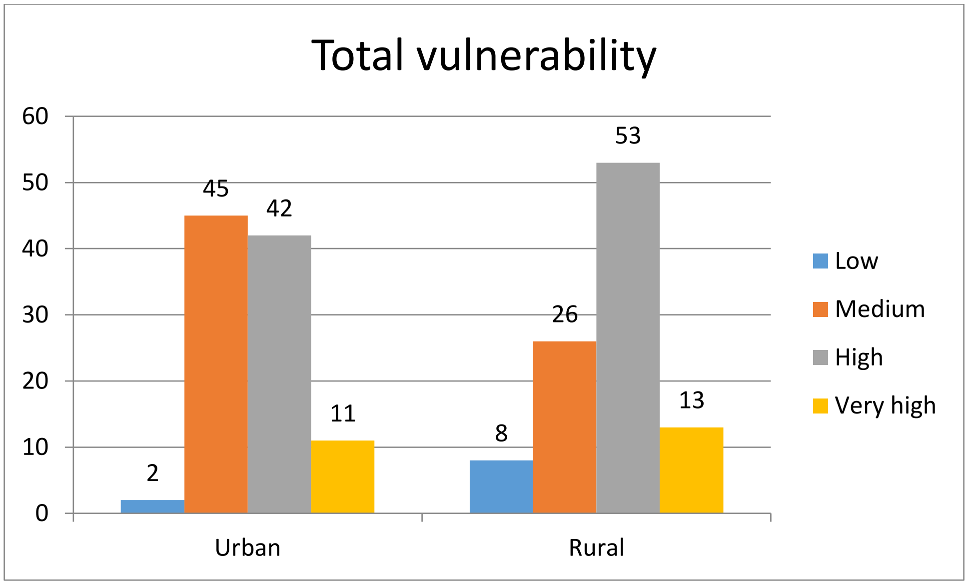


Figure 48 Total vulnerability

6 Institutional Challenges

Officials from different departments were interviewed using a predesigned open-ended questionnaire and recorded their answers. A survey was also conducted from the departments related to disaster risk mitigation and management to obtain information about the challenges they face during disaster risk reduction and disaster management. Following officials were interviewed during the survey.

- Director works (MDA)
- Assistant Director (SDMA)
- Director (SERRA)
- Ex Director General (ERRA)
- SE (local government)
- XEN (local government)

6.1 MDA

Muzaffarabad development authority (MDA) is working in the urban areas of Muzaffarabad. It is planning and managing the development of old and new construction of housing societies, commercial areas, and other infrastructural works. After interviewing officials from MDA, different challenges were noted in this department regarding disaster risk reduction.

The main challenge for this department is to implement the master plan which was made for Muzaffarabad after the 2005 earthquake. Officials said that a master plan was made to regulate the construction in the city after the major earthquake so that the population of the city would be made less vulnerable. But they are facing many issues in implementing that master plan. Officials said that there is a lot of political involvement due to which they cannot work according to the master plan. The people with political power interfere with their work if the work on the master plan goes against their personal interests. Due to this reason, working on the master plan is still pending.

Another issue told by officials is the lack of funds. They said that a lot of things should be done to reduce the vulnerability of the local population, like installing retaining walls on banks of rivers, providing sewerage systems, improving public buildings, etc. Still, due to the lack of financial resources, all these works are not done yet.

Officials also told that they are also short of working staff. They are told that if they are provided with the required working force and financial resources, they can take a lot of steps by which they can significantly reduce the vulnerability of the local population against different disasters. This is also a serious issue because it is difficult for them to regulate the building standards in a large area of Muzaffarabad due to the lack of man force. Especially they cannot pay attention to the rural areas because their man force is already insufficient for the urban areas.

Officials also said that construction is going on without any regulation in many areas of Muzaffarabad. They are unable to stop or regulate that because either it is backed by the powerful political people or it is not under the jurisdiction of MDA. They said that they are developing a housing society in Chattar, Muzaffarabad under MDA where they are observing all the bye-laws and regulations, and it is an example that if they are given the required resources, they can do the right things.

6.2 SDMA

The state disaster management authority (SDMA) is an authority that works in coordination with the National disaster management authority (NDMA). The former authorities like SERRA and ERRA working in this area after the 2005 earthquake were also merged into

SDMA. SDMA works specifically for the matters concerned with disasters. Whether these are related to pre- or post-disaster period, such as different steps for mitigating different disasters, rehabilitation works after any disaster, etc.

Officials from SDMA and former officials of ERRA and SERRA told us different issues they are facing in the study area. They said that the most serious issue they are facing is the non-seriousness of political government in taking mitigation steps against different hazards. This is mainly because a huge time has passed since the 2005 earthquake. They said they had done a lot of work after the 2005 earthquake to rehabilitate people on a very large scale. A lot of work has also been done by ERRA during the post 2005 earthquake period. They gave relief packages, shelters, and camps to the affected people and reconstructed many government buildings that were damaged during the earthquake.

But now, as time passed and the rehabilitation of the local population has been completed, the government's interest has also become less, and there is no proper policy making and implementation for the disaster risk reduction. SDMA lacks financial resources, human power, and equipment, and it cannot do much work to reduce the vulnerability of the local population against disasters.

6.3 LG & RDD

The local government and rural development department (LGRDD) is the government body responsible for monitoring and regulating the construction and development works in urban and rural areas. This department also monitors the implementation of bye-laws and the master plan made in 2007.

The officials from the LGRDD said that the current bye-laws for the construction of residential and commercial buildings require an update. They can be improved in many aspects, and the situation of the area regarding different hazards demands special additions to the bye-laws. They said there should be changes like restriction on the construction above 3 or 4 stories, soil testing and structural design for the commercial and residential buildings, etc.

Besides this, they also said there is a shortage of human resources, financial resources, and availability of some data necessary for planning and policy-making. This makes it difficult for them to implement the current bye laws in the area properly.

Another major issue listed by the officials is the increasing population of urban areas. They said that there was a significant increase in the population of Muzaffarabad after the 2005 earthquake, as many people shifted to the urban areas from the far-flung areas, and uncontrolled construction was done during this period. They said they need more staff to monitor and implement bye-laws as there is a lot of construction going on without plan approval. And even if some people get their plan approved by concerned department, they do not construct according to the approved plan and make changes according to their own desire without keeping in mind the possible outcomes. This is also one of the main issues relating to the ongoing construction in the area, which can only be regulated with the required staff and financial resources.

7 Conclusion & Recommendations

The adverse effects of any disaster can be minimized or even avoided completely by reducing the local population's vulnerability. The physical and social aspects of vulnerability can equally contribute to the overall vulnerability of any population or area. Thus, it is important to assess both the dimensions of vulnerability so that necessary steps can be taken to reduce them. Similarly, it is also important to know that inside the multi-hazard prone area, vulnerability against which hazard is high or which parts inside the hazard-prone area have higher physical or social vulnerability. Moreover, it is also important to know which area is overall highly vulnerable so that the most required steps should be taken on a priority basis.

This study found that more houses in the urban areas are pakka, have a boundary wall and have proper sewerage system compared to the rural areas. Similarly, more houses in rural areas are located away from the river and have side spaces around them. As far as earthquake physical vulnerability is concerned, more houses in the urban areas have RCC structure, good quality construction, approved plan, and are constructed under engineer or contractor’s supervision. On the other hand, more houses in the rural areas have no parapet, are isolated, have asbestos sheets used in the roof with wooden or iron supports, and have minimum wall spans. Regarding the social aspect of vulnerability, it is found that more households in the urban areas have maximum income, more knowledge about disasters, access to municipal water, and easy access to medical facilities. Whereas more households in the rural areas have their own house.

This study found that in the study area, urban areas are physically highly vulnerable to earthquakes as compared to rural areas. Whereas there is no significant difference in the physical vulnerabilities of both urban and rural areas against flood hazards. It means that proper attention is needed to reduce the physical vulnerability of urban areas to earthquakes.

Besides this, the study found that rural areas are socially more vulnerable than urban areas. And when both physical and social aspects were taken collectively, it was found that the rural areas are more vulnerable, which means that the social aspect of vulnerability is highly affecting the vulnerability of rural areas, making them highly vulnerable compared to the urban areas. Thus, all this comparison results in the conclusion that the necessary steps must be taken on a priority basis to reduce the social vulnerability of rural areas. On the other hand, the physical vulnerability of urban areas to earthquakes must be reduced.

Considering this study's outcomes, it is suggested that the data should be collected from all parts of the hazard-prone area on a priority basis. Policies and bye-laws should be made while considering the flood and earthquake hazards. Especially in the urban areas, steps must be taken to reduce the physical vulnerability against earthquakes by working on indicators that make urban areas more vulnerable to earthquakes. Similarly, necessary steps should be taken to reduce the social vulnerability in rural areas by targeting those indicators contributing to the high social vulnerability of rural areas. However, as this study focuses on comparing the vulnerabilities of urban and rural areas based on certain indicators, further studies can be done using other advanced methods to take a clear picture of vulnerability against earthquakes and floods. Moreover, this study only used the data of residential buildings; further studies can be conducted, including all the area's building stock.

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ANNEXURE

Physical Vulnerability Assessment Form (Flood Hazard)

Name of household head:_____________

Contact #:_______________________

Address:________________________

Date:___________________________

Type of building ____________________

Photo

1. Number of Story ☐ 1 ☐ 2 ☐ 3 or More	**7. Boundary wall.** ☐ Not Present ☐ Present
2. Construction type ☐ Katcha ☐ Mix ☐ Pakka	**8. Age of building (in years)** ☐ Less than 10 ☐ 10-30 ☐ More than 30
3. Heights of lowest opening in the building ☐ 2 feet or less ☐ 2 feet to 6 feet ☐ More than 6 feet	**9. Location W.R.T river.** ☐ More than 200m ☐ Inside 200m ☐ Inside 100m ☐ Next to river
4. Basement ☐ Present ☐ Not Present	**10. Building Construction on improved plan** ☐ Yes ☐ No
5. Building site elevation ☐ Plain ☐ Mid Slop ☐ High Slop of Hill ☐ Hill Top	**11. Present of Side spaces** ☐ Not Presence ☐ At one Side ☐ At both sides
6. Sewerage System ☐ Present and Covered ☐ Present but not covered ☐ Not Present	

Comments

Physical Vulnerability Assessment Form (Seismic Hazard)
For residential buildings

1. Building type ☐ Unreinforced Stone masonry ☐ Unreinforced Block masonry ☐ Unreinforced Brick masonry ☐ RC Frames with infill walls	**7. Maintenance condition** ☐ Poor ☐ Average ☐ Good
2. Building Age (yeas) ☐ >30 ☐ 21-30 ☐ 10-20 ☐ < 10	**8. Wall Type** ☐ Stone ☐ Block ☐ Brick
3. Plan irregularity ☐ Regular ☐ Slight Irregularity ☐ Irregular	**9. Apparent Material Quality** ☐ Poor ☐ Average ☐ Good
4. Vertical Irregularity ☐ Regular ☐ Slight Irregularity ☐ Irregular	**10. Mortar type** ☐ Mud ☐ Cement
5. Number of Story ☐ >3 ☐ 3 ☐ 2 ☐ 1	**11. Alterations** ☐ Major ☐ Minor ☐ None
6. Building Apparent Construction Quality ☐ Good(good connection between structural elements) ☐ Mdedium ☐ Poor (poor connection between structural elements)	**12. Dampness** ☐ Damped ☐ Slighthy damped ☐ Undamped

Comments

13. Maximum wall span ☐ 12feet or less ☐ 12 to 20 feet ☐ More than 20feet	**19. Roofing Material** ☐ RCC Slab ☐ Asbestos Sheet with wooden support ☐ Asbestos Sheet with iron support
14. Floating and hanging columns ☐ Yes ☐ No	**20. Parapet** ☐ Unanchored ☐ Anchored ☐ Improperly anchored
15. Previous Structural Damage ☐ NO Visible Damage ☐ Slight Damage ☐ Severe damage with widespread cracks	**21. Overhang Length; balcony (in meters)** ☐ < 1.5 ☐ >1.5
16. Minimum gap between adjacent Building ☐ < 100 mm per story ☐ Otherwise	**22. Heavy Mass at top** ☐ Yes ☐ No
17. Building Location ☐ Internal ☐ Corner ☐ End ☐ Isolated	**23. Construction type** ☐ Engineered ☐ Local Contractor ☐ Non-Engineered/self-supervision
18. Soil type ☐ Rock / Hard soil ☐ Medium ☐ Soft soil	
Comments	

Social vulnerability Indicators

1. House hold income ☐ 25000 or below ☐ 25000 to 50,000 ☐ 50,000 to 100,000 ☐ Above 100,000	**6. Family size** ☐ <5 ☐ 5 to 9 ☐ >= 10
2. No of disabled persons ☐ Zero ☐ 1 ☐ 2 ☐ More than 2	**7. House ownership** ☐ Owned ☐ Rented
3. Male of female ratio ☐ <1 ☐ 1 ☐ >1 ☐ More than 2	**8. House hold knowledge about disasters** ☐ NO Knowledge ☐ Only flood ☐ Only Fasthquake ☐ Both
4. No of person in age group (0-6) years ☐ zero ☐ 1 ☐ 2 ☐ more than 2	**9. Drinking water quality** ☐ Filtered ☐ Ground Water ☐ Municipal water supply ☐ Non-drinkable
5. no of person older than 60 year of age ☐ zero ☐ 1 ☐ 2 ☐ more than 2	**10. Access to medical facility** ☐ Easy ☐ Medium ☐ No access

Comments