PHYSICAL VULNERABILITY ASSESSMENT DUE TO FLOODS SIESMANDI AREA

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“**Physical Vulnerability Assessment Due to Floods - Siesmandi Area”**

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MY FATHER

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CONTENTS

LIST OF ABBREVIATIONS

PDMA	-	Provincial Disaster Management Authority
NDMA	-	National Disaster Management Authority
KPK	-	Khyber Pakhtoon Khwa
MSL	-	Mean Sea Level
RCC	-	Reinforced Cement Concrete
Ft	-	Feet
Rs	-	Rupees
RCF	-	Reinforced Concrete Frame
RCI	-	Reinforced Concrete with infill Masonry
UBM-MM	-	Unbound Brick Masonry with Mud Mortar
UBM-CM	-	Unbound Brick Masonry with Cement Mortar
WB	-	World Bank
UC	-	Union Council
PCC	-	Plain Cement Concrete

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Abstract

Global environment changes have led to increased number of floods resulting into different human, social, environmental and agricultural losses. KPK province of Pakistan was badly affected by 2010 floods. Building inventory plays a vital role in physical vulnerability & Risk assessment for floods. Building performance in a hazard like flood depends on type of building structure, its location & severity of flood. Last building inventory in Pakistan was developed in 1998-99(2017 census data not incorporated in this study). Current stock is projected as per 1998 census for according to population growth. This could not be true due to spatial variations in building stock as well as urbanization of large populations. Different techniques have been employed to develop the building inventory as per typologies. In this research Google earth images supported with actual field observations were used to calculate & classify the number & types of buildings in flood affected Siesmandi area of KPK. Secondary data analysis was followed by verification through randomly selected 402 units inside the study area. Present technique have been previously used for earthquake vulnerability/ risk assessment but for floods that too taking exposure & hazard along with elevation from MSL into account, the study is first of its kind. After creating the building inventory, physical vulnerability to floods is assessed using the employed model which could be further used for potential risk. Same result in the form of vulnerability map is used to recommend precautionary/mitigating measures in the study area for people and Government organizations.

Key words: Physical vulnerability, 2010 floods, Building inventory and typology, Qualitative Risk assessment

Chapter 1

INTRODUCTION

1.1. Background

Global environment changes are an emerging problem for most of the countries in the world. These countries are not been able to adapt to these changes as per modern modifications(Michael, 2009). Disasters like earthquakes and floods that occur naturally also make these environmental changes worse. The increasing rate in floods for the past few years; is considered more damaging and dangerous(Roos, 2003). Nevertheless, all countries of the world are at same risk due to these floods, but countries which are rich in agriculture are considered more at risk due to these disasters. These agricultural countries mostly have many rivers and streams which supply water to the crops and fields harvested in the villages and different cities(Smith, 1991). When floods come, it destroys these crops due to the overflow of the water. Where, the flood is known as the overflow of the water from the river due to different climatic changes that leads to ‘the inundation of the land’ outside water flowing stream or channel(Aufbaubank, 2006). These floods also damage the buildings of the urban cities by putting cracks in their walls and making them weak due to the continuous flow of water. The increasing damages caused by these floods make them an important topic to be discussed by the researchers(Thieken et al., 2008)

The Jochen Schwarz & Holger Maiwald’s model is considered as an important model to assess the vulnerability of the buildings and infrastructure and its damages caused by the floods. According to this model, the damages caused by the floods are graded according to their severities(Maiwald and Schwarz, 2014). Such grading of damages is described below:

- **D_1:** It includes no structural damages but slight non-structural damages. Only 'penetration and pollution' are observed.
- **D_2:** It includes slight structural damages and moderate non-structural damages. 'Slight cracks in supporting elements, impressed doors and windows and contamination replacement of extension elements' are observed.
- **D_3:** It includes moderate structural damages and heavy non-structural damages. 'Major cracks and / or deformations in supporting walls and slabs, settlements and replacement of non- supporting elements' are observed.
- **D_4:** It includes heavy structural damages and very heavy non-structural damages. 'Structural collapse of supporting walls and slabs and replacement of supporting elements' are observed.
- **D_5:** It includes very heavy structural and non-structural damages. 'Collapse of the building or of major parts of the building demolition of building' are observed. (Schwarz and Maiwald, 2008)

The main focus of this model is to focus on the damages cause by the floods to the buildings, and finally determining the classes of vulnerability for different types of buildings(Sachsen, 2011)

Floods are of different types which include: 'flash floods, river floods, coastal floods and urban floods'. The floods are also categorized according to their duration.

Such floods included: ‘slow-onset flood’ which almost lasts for a month, ‘rapid-onset flood’ which lasts for only one or two days and the ‘flash floods’ which last for a few minutes and even for few hours after a heavy rainfall(Deilmann, 2010) The storm surge, also known as the tidal surge is due to the rise of the water at the off shore. This takes place due to a tropical cyclone. It is considered as the combined effect of ‘low pressure and persistent winds’(Kiln, 2009)

The ‘riverine flooding’ is considered as one of the major problem for entire world. Even in many countries like Elbe in Germany; Indus in Pakistan; Vistula in Poland and Brahmaputra in Bangladesh have caused sufferings to the people. It has been observed that Pakistan is one of the South Asian countries which faced a lot of damages due to an increasing number of floods. Pakistan suffered from a flood in 2010 which is considered as one of the most devastating floods of all times in last decade or so. Due to the studies done specially in recent past, it has been concluded that the increasing human effects on the climate and rivers due to the increasing technology results in more damaging floods. This resulted in an immense increase in the rate of the floods for the past 30 years. The researchers are of the view that the increasing change in climate might result in an increasing number of the floods even in the future.

The financial status of a family affects the rate of vulnerability that they face. The family with the lower income living at the riverside will be relatively more vulnerable to the floods than the one with better income. The increasing population of the world is also resulting in an increase in damages due to the floods (UDNP, 1992). The harmful effects of the floods can be reduced by acting on the three important aspects, which are: ‘to reduce the vulnerability of the buildings and the infrastructure in which the people live; to reduce the vulnerability of the economic status and to strengthen the social impact of a community so that during the time of disaster, the people of the community stood by each other in order to prevent the losses as much as possible(Thomas, 2014)

There are different causes of riverine flooding. One of the main reasons of river flooding is the heavy rainfall. As a result of it, excess of water gets collected in the river and the heavy overflow of this water results in the river flooding damaging the crops and fields. Other factors that may result in river flooding include: the intensity with which the rain falls, its duration, the ability of a network of the stream to help in runoff of the water, the cover of the ground, the influence of the tides and the climatic conditions before the rain(Kelman, 2011).The breakage in dams can also result in river flooding. As the dams protect the overflow of water, a small breakage in it can lead to overflow of water resulting in floods. It has been observed that the hurricanes can also carry water from the coastal areas to dry lands resulting in the floods. Another reason for the floods may be the melting of the ice present on the mountain tops. It has been observed that the ice covering the mountain tops, when melts, results in the heavy flow of water resulting in the flooding(Sachsen, 2010)

Floods also have impacts on ‘human loss; property loss; damaging of main roads; distribution of air, train and bus services; spread of water-borne communicable disease; communication breakdown; cut off of electricity supply; economic and social disruption and increase in air and water pollution. In order to prevent these losses, the water ways built for the water are made better and more reservoirs are built to stop the overflow of the water. Near the riversides, ‘different erosion control measures’ are taken to slow down the process of agricultural loss (Schwarz and Maiwald, 2012)

Vulnerability of buildings is largely because of the construction of wrong building in the wrong area. Some of the damages caused by the floods to the houses and small buildings include: wash away of houses due to the overflow of water under the high velocity stream; the houses float due to the rise in water; the inundation of houses also occur in which, the house remains firm on its base while its materials get damaged due to the continuous water flow; the intense velocity of the water may also damage the building and the trees and other houses floating in the flood may also damage the houses that remain firm on their bases(Schwarz and Maiwald, 2012). Health of the individuals is also affected by floods resulting in more deaths than the injuries. The surgical needs required during the floods are only for 72 hours. One of main reasons for the cause of deaths during the floods is the bite of the venomous snake (Corporation, 2017)

Many agricultural hazards are also observed due to the floods. It has been observed that the agricultural countries are more at risk due to the floods. According to the reports, in 1975 almost 48 percent loss was observed in agriculture as a result of river floods in the U.S.A. These floods result in loss of crops due to drowning. The erosion of the upper layer of the soil is another negative impact of the flood(Hoblit et al., 2002). Flooding however is not considered as a completely bad thing for the agricultural sites, as it helps in removing the dead layer of the soil and providing the space for a new one and by enriching the soil by providing the required nutrients and minerals to the soil for proper growth of the crops. It further helps in diluting or completely removing the pollutants. The ecosystems of the rivers can be maintained by providing; ‘breeding, nesting, feeding and nursery areas for fish, shellfish and migrating waterfall’(Allen, 2017)

The typical adverse effects of the floods include: ‘the loss of life; the loss of property; the structures like roads, building and houses also get damaged; lack of proper drinking facilities; spreading of viral infection like malaria; inundation of the agricultural area resulting in increasing loss of crops; the removal of the upper layer of soil may also result in depletion of required nutrients(Parashar, 2017)

In order to protect the buildings from the hazards of the floods, different arrangements are done. The floods can also make these buildings vulnerable. Different building materials used in the buildings include: cement, clay, wood, bricks, steel or iron. The variations in the sites of construction and a poor supervision of the buildings from the government level also increase the vulnerability of these buildings to the floods. Different measures require for risk reduction include: ‘mapping of the flood prone areas; land use control; construction of engineered structures; flood control (detection, flood proof and channelization) and flood management. Flood control is the main factor required to reduce the damages caused by the floods. For this purpose, the runoff can be decreased by ‘reforestation; protection of vegetation; clearing of debris from streams and other water holding areas, conservation of ponds and lakes’(Alliance, 2017)

The velocity of the water also affects the damages cause by the floods. Such damages include the erosion of the building and damaging of the materials of the buildings. Different detention facilities are used in order to decrease such damages. These include the dams and to store the flood waters which reduce and eliminate the need for other control facilities of the flood. One of the disadvantages of these facilities is that it creates a false perception in people's minds regarding the protection provided by them against the floods. These facilities never provide a complete protection against the floods instead; they are designed to give other ways during the floods(Hussain, 2017)

1.2. The problem statement of the study

Frequency of floods in recent past has increased attributed mostly to climate change & variability. This resulted in human losses, buildings and agricultural losses. Agricultural industry suffered a lot from the riverine floods from the past few years. This problem is more common in countries which are rich in agriculture. Even the barriers made to stop these floods were becoming weaker in front of the overflow of these floods. However, sometimes these floods also help in enriching the soil by removing the upper layer of the soil in order to provide the required nutrients for better harvesting of crops.

Selected study areas located inside Nowshera district were severely affected due to 2010 floods in Kabul River. Here residents are generally poor with an annual income of less than Rs 300,000. Location of villages makes its community vulnerable to floods. Community is not aware of disaster risk reduction& lacks coping capacity.

Building codes are not followed in construction. Poverty is widespread resulting in lack of resilience to disasters, construction of mud houses, lack of education & poor infrastructure are all contributing to physical vulnerability. Areas are located adjacent to Risalpur cantonment with people working inside PAF & Risalpur Cantonment making it a security hazard should relocation trigger due to floods. There is a need to assess existing physical vulnerability of building stock due to flood. Susceptibility to harmful effects to buildings and locations shall be categorized into vulnerability classes using established vulnerability scores for subsequent guidelines & implications. Different measures required to prevent these floods, should also be discussed. These measures may include the adoption of better engineered structure to prevent them from getting damaged by the attack of the floods. The flood control and management are also required for preventing the increasing rate of the floods. Dr Naveed Ahmad model was used for this study which also helped in collecting the data and assessing it properly to obtain better results. Same model is used to classify the entire Punjab province for physical vulnerability assessment and risk mapping as assigned by NDMA / PDMA Punjab Pakistan. Data is collected for different types of buildings which include the clay building or the adobe structures, Reinforced concrete framed structures, Reinforced concrete with infill masonry, unbound brick masonry with cement mortar and unbound brick masonry with mud mortar. Using the building classifications as identified on ground and by use of the vulnerability scores the vulnerability of the buildings due to floods is determined. Later using the elevation levels from mean sea the area which is divided into smaller areas of 100 m x 100 m grids, the vulnerability assessment and vulnerability mapping is done.

1.3. Rationale of the study

- The research has professional needs for the researcher as topic clearly falls in domain of civil engineering. In disaster management field a little work is done keeping in view flood effects on structures. The outcome of the research shall produce a risk map of the study area which can be used for pro-actively placing resources for disaster management in required areas.
- It has contextual needs as well. The flood events of recent years have shown that even extreme events with very low probabilities of occurrence are very much possible and can result in devastating damages.
- In comparison to other areas of hydrology and water management only few damage data and applicable models are available, which can be used for reliable prediction of flood damages to physical structures
- The data of vulnerable areas/buildings obtained through Google earth/arc GIS shall be validated by on field surveys through questionnaire. This shall encourage potential users to follow the engineering approach and to take field surveys for vulnerability assessment and risk mapping for qualitative loss assessments from floods.
- The method is used for the 1st time for qualitative risk assessment of the area against floods by taking both aspects of the exposure i.e buildings and ground elevation.

1.4. General interest of the study

Environment changes and variability is resulting in different types of floods which is causing both human and economic losses. The most common type of flood are the riverine floods which occur due to the overflow of the water in rivers and other streams. This leads to the destruction of life and property in particular agriculture industry. Different precautionary measures are required to be taken in order to decrease the damages caused by the floods and even the social harmony among the people also plays an important role for this purpose. This required studying the physical vulnerability of the built in infrastructure for subsequent mapping and making building inventory.

1.5. Objectives of the study

The research is aimed at achieving following objectives:

- To develop building inventory by identifying existing building stock and its typology for the selected areas.
- To assess physical vulnerability against floods for building stock inside study area using vulnerability scores for different building types.
- To Create vulnerability map for the area taking both building infrastructure and ground elevation from mean sea level into account
- To recommend precautionary measures for reduction of damages to buildings and infrastructure due to floods.

1.6. The research questions of the study

The research questions of the research study include:

- What are different types of buildings in the study area?
- How the vulnerability to floods of the selected building stock for the subject areas can be assessed?
- What vulnerability scores are used based on vulnerability functions to assess the vulnerability and qualitative risk assessment and on what basis?
- How to make qualitative risk map of the area taking exposure and flood hazard into account
- What precautionary measures are recommended to reduce the damages to buildings and the infrastructure due to floods?

1.7. Scope of the research study

The primary scope is Pakistan's flood affected regions in which KPK is the most vulnerable one. KPK is one of the most productive provinces of the country as it is enriched with natural resources. The current incumbent government of Pakistan has built dozens of small scale dams in the province. However results have not been yielded as perceived as these dams are mostly low storage reservoirs. Secondary or the inner scope of the study shall be the areas astride river Kabul in district Nowshera namely Siesmandi and Kanderi. It's a 10.4 sq. km area along river Kabul which has been inundated in all recent big floods. So for specific examination, the study shall consider the region to be selected for field work as well as for data collection.

The basic statistical data including, the ‘health, education, socio-economic statuses’ of the population is obtained from the required resources. This help in providing a better outlook of the damages caused due to floods. This lead to the use of different measures, required to protect the buildings and crops from the damage due to the floods. The Google earth pictures and information was used to convert in arc GIS and study was carried out in layer for making building inventory and subsequent mapping.

1.8. Organization of the study

There are five chapters in this research dissertation which are following:

Chapter 1: It includes introduction in which background, problem statement, research objectives, research questions, significance, scope, general interest and thesis layout is given.

Chapter 2: It includes literature review and Theoretical Framework. In this chapter, previous studies regarding floods, types of floods, causes of the floods, vulnerability assessment for the floods, types of losses occurred because of the floods, flood vulnerability assessment of KPK on random sampling, physical vulnerability to floods of buildings & materials as per typology and different models used for physical vulnerability to floods are discussed.

Chapter 3: It includes research methodology and in this chapter; research philosophy, approach, method, nature, sampling details, measures and ethical considerations will be given.

Chapter 4: It includes results and analysis in which results of the survey done including the making of final qualitative risk map.

Chapter 5: It includes discussion and conclusion in which key findings will be discussed to debate on hypotheses acceptance or rejection. Furthermore, conclusion, implications, limitation and future research indications will also be there in this chapter.

Chapter 2

LITERATURE REVIEW

This chapter includes literature review of ‘floods, types of floods, causes of the floods, general characteristics of building typology, spatial pattern for building typology ,the impact of floods on physical vulnerability of buildings and its materials explained as per the topology, floods in Pakistan, random sampling method used to assess the flood vulnerability in KPK, essential losses required to be focused, vulnerability assessment for the floods, hazus loss prediction model and Jochen Schwarz & Holger Maiwald’s model’.

2.1. Floods

Floods take place due to climatic and environmental changes. An increase in the rate of floods these days has made it an important issue for research. For this purpose, a lot of research is now being done on the floods taking place in different countries in order to assess the different causes for their occurrence and the precautionary measures that should be taken to prevent them.

The research in floods helps in providing a better data for the assessment of number of floods taking place in the world throughout a year. For this purpose, a U.S. policy was stated whose main aim was to focus on the flood control. It was observed that the damages due to the floods were increasing day by day and the congress was not even able to control the hazardous effects. However, the policy of flood included four issues that were continuously changing which were: ‘the responsibilities that were shifted from the federal to the local-state responsibilities; the National Flood Insurance Program; the shift to nonstructural approaches for flood mitigation; and developing programs for emergency assistance'. The purpose of this research was not only to enlist the damages caused by the floods but also to observe the significance of the floods which they had on the agriculture. The socioeconomic data was collected in order to assess the required factors. It was concluded that sometimes the floods also show efficient behaviors by removing the upper dead layer of soil to enrich it with the required nutrients and minerals for harvesting crops(Changnon Jr, 1985)

The history of the United States includes many cases of the natural disasters that take place due to the floods. One such flood that took place in 1993 was stated. It was known as the Great flood. This flood was drastic enough to destroy the residents of the three Midwest towns present in the United States. The stated research was done in order to understand the effect of community behavior on the flooding. Another project was designed to determine the social effect of the community in response of the flood. This study included three communities. The methodology used for this study included the collecting of the data, interviewing and a questionnaire survey. The data collected from this survey was later assessed properly by using the stated methods. It was concluded that the flood had a great effect on the social behavior of the community as the people developed a more sense of caring towards each other during such difficult situations(Schwab, 2012)

2.2. Types of floods

Different studies have been done regarding the types of the floods in past years. As classifying the floods also help in understanding the different damaging effects of different types of floods. Few such research studies are discussed below.

Classifying the 'flood types' plays an important role in clustering the floods according to the similar 'meteorological triggering conditions'. It has been observed that changes in climatic conditions result in different types of bloods. For this purpose, 'a natural rainfall runoff model' was coupled with a 'weather generator. This helped in recording a large number of flooding events. From the above model used, different rates of rainfall were measured that helped in assessing the type of the flood that might be caused by them. This study lead towards a better methodology required for a better flood management and risk management. This also improved both the social as well as ecological systems of the society in the future(Turkington et al., 2016)

Three common types of floods were discussed which included: 'coastal (surge flood); fluvial (river flood) and pluvial (Surface flood). Coastal flood takes place in the areas which are at the sea shores or at the riverside. This type of flood is divided into three levels which are minor ('a slight amount of beach erosion with no more damage'); moderate ('a fair amount of beach erosion as well as some damages to houses') and major ('it is the serious threat to life and business').Where, the riverine flood occurs because of the overflow of the water from the river due to the excessive rainfall. River flooding is of two types which include: 'overbank flooding' (which occurs due to the overflow of water from the edges of the rivers or seas) and 'flash flooding' (which occurs due to 'high velocity torrent of water' resulting in destruction of the masses). The surface flood occurs due to 'heavy rainfall' without any overflowing of the water. There are two of surface flooding which include: 'intense rate of rain falling, an urban drainage system and the falling of the water from the hill tops due to the rain falling on them(Maddox, 2014)

Different types of floods were also reported on the basis of their duration. These types of floods included: slow-onset floods; rapid-onset floods and flash floods. This study stated that the floods which have duration of longer time i.e. more than one or more weeks or months are known as slow-onset floods while the floods which have duration of shorter time i.e. only one or two days are known as rapid-onset flood. According to the discussed study, the flash floods are those which occur within few minutes or few hours(James, 2014)

2.3. Causes of floods

Different causes of floods have been observed for the past few years. The major cause that was observed was the drastic change in climatic conditions. The other reasons may include the damaging of barriers like dams and bridges, running of water from the tops of the hills due to heavy rainfall and many others.

An increasing rate of the floods is becoming the talk of the town for the past few years. Different studies are conducted in different countries to know the causes of the floods in the specific area. One such study conducted in south western Nigeria stated that the increasing rate of floods was due to the climatic changes that occurred because of the changing living conditions of the people living in urban areas. As the increase use of modern technology by these people lead towards the global warming thus the number of floods also increased from the past few years. In order to collect the data for this stated study, 240 urban families living in south western Nigeria were interviewed. For this purpose, different documentaries that were played on the radios and televisions were considered. It has been observed that the magnitude and the floods occurrences were increasing and the Government was becoming more concerned about the issue and specific measures required to solve this problem. It was concluded from this study that the living conditions of the people living in particular area also have an effect on the climatic changes (Nwigwe and Emberga, 2014)

The scientific research has also been done to determine the causes of floods. Different engineers, researchers and scientists worked together to determine the different causes of the floods. For this purpose, they studied the different chemical hazards and the agricultural damages caused by the floods. This helped in enlisting the real causes behind these damages. The study stated mostly focused on the impact of floods on the flora and fauna of the areas. The environmental assessment was done. As a result, the models for ‘flood environmental and strategic environmental management of flood’ were formulated. It was concluded that the floods can be prevented by applying the required methods properly(Gautam and Van Der Hoek, 2003)

Riverine flooding is one of the common types of flood. Different studies have been done in order to determine the causes behind this type of flood. The causes behind the riverine flooding included: ‘a steep sided channel, a lack of vegetation or woodland and a drainage basin in an urban area’. A steep sided channel included a fast run-off of water due to steep slopes. The plants and trees help in preventing a lot of environmental disturbances even the floods. So, the lack of vegetation or the woodland lead towards a loss of barriers required to prevent the overflow of water. A drainage basin in an urban area consists of a large concrete rock which does not let the water to pass through it and it results in an overflow of the water causing extreme damages. It was later concluded that the riverine flooding was caused due to many reasons and the most common included: 'a steep sided channel, a lack of vegetation or woodland and a drainage basin in an urban area' (Loucks and Van Beek, 2017)

2.4. General Characteristics of Building Typology

The types of construction materials used in constructing a building play an important role in order to understand the damages that can be caused by the floods to them. Few studies were done regarding this in the past. Such studies are discussed here.

The building typology includes the different types of construction materials used in the construction of different parts of a building including roofs, walls and floors. It includes the 'building construction units such as the type of masonry units; structural load bearing elements including masonry walls, wooden frame and concrete frame; binding material used in construction of walls such as cement mortar and mud mortar and material constituent used in the construction of floors/roof such as reinforced concrete floors, reinforced concrete-brick floors, wooden logs provided with straw and heavy mud flooring, roof trusses of wood or steel(Mudavanhu, 2014).

The masonry buildings of the unreinforced bricks are becoming more popular in the urban and more civilized areas of different countries. One of such study done in Pakistan showed that the ordinary masons were used to build such buildings in Pakistan by using the thumb rules. It was observed that the buildings were constructed in the regions which had one to three storeys as it was restricted by the municipal authority to build a building higher than three storeys. But some buildings were even seen built with four or five storeys. It was concluded that most of the buildings built in the urban areas were masonry with unreinforced bricks(K, 2009)

The fired bricks were used in the 'cement mortar' for constructing 'one-way the load-bearing masonry walls'. For this purpose, a masonry building was selected. The floors and roofs of the building also contained the unreinforced bricks. 'The light beam girders, steel joists and the wooden joists' were also used in this building. It was also observed that the 'lightly reinforced vertical confining elements' were also being used at the corners of the walls of the building. However, the buildings in the rural areas consisted of the bricks in the 'mud mortar' and the roof was made up of wood with heavy mudding. It was concluded that the 'Block Masonry construction' also used these construction materials and methods(Mudavanhu, 2014)

Different types of buildings are constructed following different methodologies. 'Stone Masonry Construction' includes the buildings located in urban areas which use the stone blocks with the reinforced bricks in the cement mortar for constructing 'one- or two-wythes walls'. The wood joists and the steel joists are used in the upper roofs of such buildings. While in rural areas, local stones from the fields are used to build houses. While the hard wooden surface was used as roof- top, with the use of mud(Caunhye et al., 2012)

Common type of construction use in both rural as well as sub-urban areas is ‘Adobe Masonry Construction’. It consists of ‘masonry walls which can bear heavy loads with a roof made up of mud. The clay dried in the sun is used in the mud-mortar or the straw-mixed mud lumps’ drifted in a wall. A ‘wooden truss roof’ is used which consists of wooden joists and steel joists. This type of construction is not considered appropriate for building a strong building which can resist the damages of the floods(Jonkman et al., 2008)

These days, the concrete construction is being used in constructing different buildings and houses especially in the urban areas. It has been observed that most of the concrete buildings consist of only 2 to 5 storeys while some concrete buildings with 10 to 15 storeys were also present. However in some larger cities like Karachi, Pakistan; concrete buildings with 10 to 20 storeys were also present. The concrete buildings constructed for commercial purposes like hospitals, plazas, hotels etc. consist of rc frames in the structure. Three sided (which included two parallel sides and one orthogonal) infill-frame is used in this type of construction. It was also observed that no space was present Between the concrete bricks and these in fills. This type of construction is considered better for constructing a strong building(Poff and Zimmerman, 2010)

The Wooden and Timber Constructions are used in constructing the buildings or houses present in the mountain areas. For this type of construction, the wood material is used instead of the local stones or mud. The infill of masonry ruble stone along with the parallel timber walls are a part of the construction structure in remote areas. Moreover, the constructions of walls are based on utilization of vertical level wooden posts and are filled with rubble masonry. Furthermore, the wooden roofs have been an essential part of these constructions. There are other traditional forms of construction of wood that involve Taq also known as Bhatar. This construction constitute of masonry and infill walls. The walls and floors are tied through utilization of horizontal bands that are locked through the burden of masonry. The Taq construction is seen in mountain areas; though its usage is limited as compared to the Dhajji structures. Moreover, another form of wooden construction involves the timber-based that constitute of random infill of masonry. The system of roof and walls are based on lighter truss in this wooden construction. The wall frames are formed by the vertical level posts along with horizontal top posts that are facilitated with horizontal along with diagonal braces of wood that are further filled with infill of masonry(Grünthal, 1993)

2.4.1. Spatial pattern for building typology

The land data of the provisional and district regions is collected from the satellite imaging obtained from the Google earth. It shows the clusters of the specific areas selected for the stated study. This method is used to determine typologies of different buildings. The information on the materials used for the construction of the building was also collected which is considered important for the study. For this purpose, the population living in a district was randomly divided into grid cells with dimensions of 1 km ×1 km. it was concluded that the spatial pattern plays an important role in determining the building typologies (Maiwald and Schwarz, 2009)

A specific method is used for the mapping of the areas. The relative distribution of the buildings present in each district is recorded according to the UC levels. For this study, the katcha and semi- pacca houses of Bahawalpur City were observed. It was observed that these houses make this area more vulnerable to the floods. The required precautionary measures (which include the construction of strong buildings by using concrete and rocks in the cement mortar) should be used to prevent the loss(Yeh, 2006)

2.5. The impact of floods on physical vulnerability of buildings and its materials explained as per the topology

The topologies of the buildings play an important role in determining the physical vulnerability caused to them by the floods or other disasters. As different construction materials used in manufacturing of building show different impacts towards the floods so their assessment should be done separately in order to determine the effects of the floods on them.

As the building typology plays an important role in determining the impact of floods on its physical vulnerability, a lot of past studies were done to explain the reasons behind it. One such study was conducted by (Sagala, 2006). For this study, a questionnaire survey was conducted for which 254 households along with 6 different types of buildings were selected. The 'vulnerability curves' were drawn to show the relationship Between ‘the depth of the flood and damage caused due to it’. It has been observed that the buildings which were made of the plywood or the wooden materials were mostly affected by the floods than the other construction materials. Whereas, the buildings which included concrete and hollow blocks in their construction, are more resistant to the damages caused by the floods. The rate of the vulnerability to the materials present inside the building was related to the number of floors present in it. The results obtained showed that the buildings which had one or two floors were more vulnerable to the floods than the buildings with more than two floors. This study also stated that the damages to the outer portion of the building were rarely observed. It was concluded from this study that the awareness to the floods and reasons behind it can help the owners to select such materials for construction that can help in preventing the damages caused by the floods to them. The knowledge about the materials used for the construction of the building should be provided such that they show least amount of damages during the floods(Schwarz and Maiwald, 2012)

2.6. Floods Vulnerability Assessment

The future losses are considered important for those who have to manage facilities and the public administration in the regions which are more prone towards the hazardous effects. These people are also responsible for developing and physical planning of an urban region. The loss is estimated by those who manage the vulnerability to the physical damage to the buildings. The insurance as well as the reinsurance companies are responsible to insure the facilities required to prevent the future losses(Kevin, 2009). In the same way, the estimation of loss is important for those who are responsible for 'civil protection, relief, and emergency services' in order to enable the adequate contingency plans required to be prepped. The draft building or the practice codes required for construction are also considered. Their task is to make sure that proper protection is being provided at little cost by using these codes(Hassam, 2009).The estimate of loses are based on type of users; for instance, the human causalities along with the ratio of homelessness might be the priority. While, on the other hand the physical losses that includes the buildings, equipment along with the infrastructures are the primary focus. Moreover, the secure measures of cities and areas that possess the disaster history have become an essential focus while development planning for future in order to overcome the hazards and disasters of future(lunger, 2013). In doing so two planning processes have been observed to be the primary focus that are;

- **Preparedness planning.** This process is the introductory phase that involves the exigency measures to deal with emergency situations.
- **Mitigation Planning.** On other hand this planning incorporates the long term usage of land, quality of stock and building along with other essential measures to decrease the influence of issues when it occurs eventually.

Furthermore, it has been viewed by past literature that the most important necessity of these planning processes is to understand and focus on what actually needs to be expected. Moreover, it requires to be quantified in either an approximate way or a crude manner in order to understand the probability of the risks that could be faced; the size of any hazard event that could occur and to take into account the consequences of event that could occur. Furthermore, in case of long term planning for developments, the social interruptions along with the economic losses must also be focused and estimated(Mohammadi et al., 2014)

The social vulnerability is considered as one of the most important aspect of the floods especially the riverine floods. For this purpose, a study was conducted in Germany in order to determine the effect of riverine flooding on the social behavior of the community. Three main indicators were observed for this study which included: 'fragility, socio-economic conditions and region'. A factor analysis can be used to determine these indicators of the selected demographic parameters. These indicators are also needed to be updated annually on the basis of the obtained data. Different vulnerability patterns were used for this purpose. For this study, three sectors of the federal region were selected. The data collected during this study showed that the vulnerability was more often seen due to the riverine floods. It was observed that the elderly people and the people with poor income were more at risk than the other people. It was concluded from this study that the damages cause by the floods also has an impact on the social lives of the individuals of the society(Fekete, 2009)

2.7. Essential losses required to be focused

Different types of losses are observed during the floods. These losses may be related to the human life or the physical instabilities. To save the human life is the top priority of a government during the times of crisis.

It has been observed from the last few years that the number deaths increased than the injuries. The floods and the smoking were considered as the important reasons for the loss of a large number of human lives. The disasters can take place due to a number of parameters that must also be considered. From the medical point of view, the risks of injuries are considered more important as the treatments should be given during such states in order to protect the people from getting more serious. Different types of losses are considered as each one of them is needed to be enlisted in order to prevent them from happening in the future(M.Nazariha, 2010) .

One of the most important losses is the economic cost because any type of the loss can result into the economic cost. The currency can be used to determine a wide range of the drastic effects. The tangible losses are considered to be the effects which are determined in terms of the economic costs whereas the intangible losses are those which are considered to be very important but they cannot be converted into a 'monetary equivalent'. In order to have a complete assessment of the risk, both tangible and intangible losses along with other different qualitative losses are considered. The qualitative nature of such losses makes them impossible to be differentiated into any single indicator related to determine the impact of such disasters. This can be explained by comparing 'the environmental degradation and the social disruption'. As both the losses are of different natures, so they cannot be comparable. The deaths and the tangible costs due to the physical damage are greatly observed during the risk analysis(Díaz et al., 2015)

In order to determine different losses caused by the floods, a lot of research work was done in the past. Few such studies are discussed here. A study conducted in India stated that a lot of human as well as economic losses were observed in 19 states from the years 1980 to 2011. It was observed that such floods result in the loss of morality of the humans and many economic losses. The Human Development Index (HDI) has helped in minimizing the moralities related to the floods. This study also includes the data collected to assess the economic losses and the rate of disasters faced by these states. The IV Tobit model used in this study showed the inverse relationship Between the disaster expenditure and the economic losses that take place due to the floods. The IV Poisson model can also be used to determine the impact of floods on the economic losses. It was concluded from this study that a lot of economic losses were observed as a result of the floods(Parida, 2011)

The loss and damages that take place due to the climatic changes are considered important in order to prevent them from happening in the future. For this purpose, a study was conducted in Limpopo, Zambez to determine the losses that took place due to the floods and other environmental changes. A questionnaire survey was conducted for this purpose including a sample size of 303. Different research tools were also used for a qualitative study. It was observed that the floods resulted in drastic effects on the agricultural industry of the selected state. The overflow of water destroyed the crops resulting in chaos by the farmers. This was because the selected state was located in the low lands near the rivers without any barriers to prevent this loss. These losses lead towards damaging of the crops thus resulting in poor income. This loss also resulted in shortage of availability of the vegetables and fruits in the markets for the people of the state. It was concluded from this study that any type of damages caused by the floods always lead to the economic losses(Brida et al., 2013)

2.8. Floods in Pakistan

Pakistan has a very large agricultural industry, but it is also moving towards being an industrialized economy. It has been observed that Pakistan is suffering from an increasing number of floods every year. The main reason behind this is considered to be the poor management used in preventing these floods. A lot of precautionary measures were taken in order to prevent the damages caused by the floods but the buildings present in urban areas still are not completely safe from the floods. Punjab and KPK are the two provinces of Pakistan that are at high risks of damages caused by the floods. This is due to the presence of rivers in these provinces(Ahmad, 2015)

The number of floods has been increasing day by day in Pakistan. KPK is mostly considered to be attacked by the floods. One such flood took place in KPK in 2007 killing almost 130 people and making almost 2000 people to migrate to other provinces. These floods continue to take place till 2010. The main cause for the floods was the monsoon rainfalls. Such disasters have also been observed for the last few years. Although, the Government is trying its best to apply the precautionary measures that are required to improve the damages cause by the floods(Ali, 2008)

Different priorities are been given in order to protect the urban and rural areas from the damages cause by the floods. For this purpose, different areas which are considered to be sensitive to the floods are enlisted and their building typologies were used to prevent them from the hazardous effects of the floods. However, this did not result in better prevention of the buildings to the floods. It was also observed that these floods also resulted in economic loss in addition to other losses. It was concluded that the main reason for the floods was the absence of better water storage areas(Jain, 2011)

A study was conducted that showed that the developed countries like Australia, Japan, U.S. etc. have better water storage areas and they are also working hard in order to develop other precautionary measures to prevent the damages caused by the floods. These countries are already facing many natural disasters but they still are developing future plans to stop them and most importantly to prevent them. However, the countries of the sub-continent such as Pakistan and Sri Lanka so not have proper resources to prevent the damages cause by the floods. These floods result in human losses as well many other physical losses leading towards an economic loss that is not bearable by these countries. This study also stated that the living ways of the people also contribute towards the climatic changes that result in the disasters caused by the floods. In order to prevent these damages, the infrastructures of the buildings should be made strong. It was concluded from this study that although the developing countries do not have proper resources to prevent the damages cause by the floods, but the Governments of these countries are still trying to prevent them(Qasim, 2010)

2.8.1. Random sampling method used to assess the flood vulnerability in KPK

As KPK is highly affected by the damages caused by the floods, a study was done by (Said Qasim, 2017) to assess the vulnerability caused by the floods in KPK. For this purpose, a questionnaire survey was conducted including 280 households. Random sampling method was used to select these respondents. For this study, three areas were selected including Peshawar, Charsadda and Nowshera. The results obtained from the survey showed that the vulnerability to these areas was very high and proper funds were required in order to the help the effected people. A ‘socio-economic uplift’ was also considered important for improving ‘the adaptive capacities’ of the selected communities(Qasim, 2017)

2.8.2. Hazus Loss Prediction Model

The Hazus Loss Prediction Model was proposed by the ‘Department of Homeland Security Federal Emergency Management Agency Mitigation Division Washington, D.C.’. this model is used to estimate the loss done by the damages of the floods by using the vulnerability assessments done regarding them. It also helps in planning the ‘flood risk mitigation, emergency preparedness, response and recovery’. The methodology use for this purpose includes all the factors of the construction for the internal environments of the buildings(Josh, 2009)

The databases are collected to determine the losses that took place at a region. The factors included in the database are: ‘demographic aspects of the population in a study region, square footage for different occupancies of buildings, and numbers and locations of bridges’. The methodology used in this model is flexible enough to collect the data regarding the local regions as well with full accuracy. This method is mostly used by federal as well as the local agency. It is considered that the uncertainties are considered as inherent in such model. The following limitations should be properly considered by the user of this model:

- This model is used to predict the losses faced by a single building. However, it should be used as the average loss.

- In order to characterize 'the lifeline system', the collected databases and the assumptions used should be incomplete.
- A small number of buildings are used to assess the required results using this model. This makes it more sensitive to errors. However, necessary cautions should be taken to prevent this(Scawthorn et al., 2006)

2.8.3. Jochen Schwarz & Holger Maiwald's model

The Jochen Schwarz & Holger Maiwald's model is considered as one of the most important model to assess the vulnerability of the buildings and other damages caused by the floods. According to this model, the damage grading (D_1, D_2, D_3, D_4 and D_5) is done to rate the damage caused by the floods.

The damages caused by the floods to the buildings can be determined by different methods. One such study done included the use of Jochen Schwarz & Holger Maiwald's model'. This model was applied on the Saxony flood that took place in 2002. For this purpose, different databases were collected including the types of buildings that were affected and the materials used in them. The damages were graded to be of D_4 type. It was concluded from this study that a lot of improvement was needed in order to determine the losses caused by the floods(Maiwald and Schwarz, 2009)

Different types of models are being proposed regarding the estimation of the damages caused by the floods due to an increasing number of floods these days. For this purpose, different such models were studied. However, 'the Jochen Schwarz & Holger Maiwald's model' was considered as the most important and efficient model required estimating the damages caused by the floods. It also includes the application of the building typology that helped in knowing the real cause behind the damages done by the floods. This can lead to the knowledge of precautionary measures required to prevent such losses(Maiwald and Schwarz, 2014)

2.8.4. Dr Naveed Ahmad's model for Physical Vulnerability Assessment

The procedure included for the vulnerability assessment of a region starts with the identification of natural hazards within the area of influence that, if may occur, can have adverse effects on the built environment and communities in the area of interest. This primarily focuses on the classification, prioritization and likelihood characterization of hazards in the region. The historical database (national and international), various relevant national monitoring and recording organizations, neighboring countries relevant research and the community itself (through conducting workshops and interviews in the locality) can help provide information on the identification of prevailing hazards in the region. The location (spatial distribution), frequency (distribution in time) and magnitude of identified hazards can be obtained from the record database

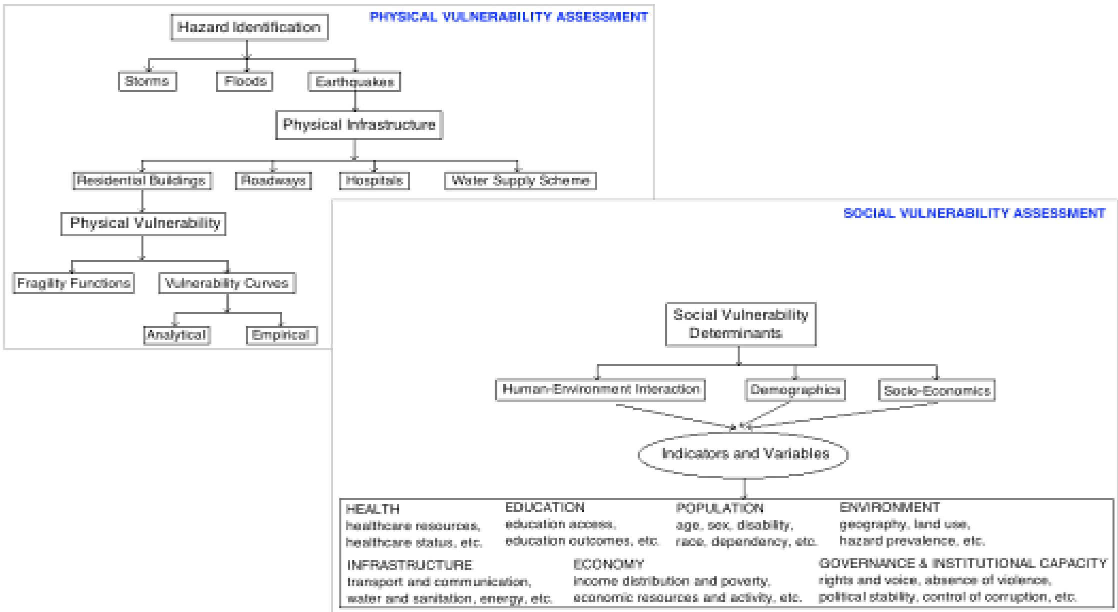

Figure 2.1: Flowchart for Physical and Social Vulnerability Assessment (Ahmad et al., 2016)

Once the hazards are fully characterized, it is followed by the definition of assets exposed to hazards; this included physical infrastructures and the community people. The physical infrastructures are defined in all aspects (location, geometrical and material properties) relevant to each hazard that help describe the performance of infrastructures against the hazards. Depending on the scale of vulnerability assessment (e.g. per structure, per block, per uc, tehsil and district level), the infrastructures are classified in various groups (those with similar structural characteristics are grouped in one class). Each of the group is assigned with the relevant damageability (fragility functions) and reparability (vulnerability curves) that correlate the hazard severity with the damages the infrastructure can incur, if subjected to that hazard level as highlighted in figure 2.1. Infrastructures fragility and vulnerability may be obtained from the available database or derived using relevant analytical (engineering calculation based, supported by numerical and/or experimental work) or empirical (past observations based or expert opinion based) procedures. The population characterization is included that involved identifying the community characteristics i.e. demographics and socio-economics, that can increase/decrease the potential for harm (human and economic losses). Population census, historical database and stakeholder consultation can help guide in the selection of more relevant drivers and indicators. The community characteristics are grouped in various indicators (drivers for increasing/decreasing vulnerability), which are standardized and homogenized and included in a framework, through statistical principal component analysis (PCA), to identify the factors that contribute the most to the vulnerability characterization of communities relatively. Once the controlling factors are identified, these are included in an additive model (respecting that each factor is assigned with its directionality i.e. increasing/decreasing vulnerability and weightage of each factor is also computed and may be included in the additive model), which gives estimate of social vulnerability factor F (an overall vulnerability aggravating factor).

For physical vulnerability mapping, vulnerable score for each structures & infrastructures are obtained, which is convolved with the respecting exposure (e.g. number of structures of a similar characteristics) to calculate the vulnerability of the considered structure class. It is integrated over all the structure types in a given area to obtain to the total vulnerability of the area. Following the spatial pattern of the exposure and their typologies, a distinct pattern of the vulnerability can be obtained.

This help in mapping vulnerability spatially, distinguishing areas with low-to-moderate-to-high vulnerability, that can in turn help in risk prioritization and budget utilization for disaster risk management towards risk mitigation.(Ahmad, 2016)

2.9. Knowledge Gaps

- Existing models which are used for building vulnerability assessment especially the Holger Maiwald's model and Hazus models were developed basically for European Building Typologies which could not be applied directly to the types of buildings in Pakistan.
- Currently no flood vulnerability assessment in Pakistan is based on building inventory, although earth quake assessment is done the same way. So the method utilized for flood vulnerability assessment is for the first time in Pakistan.
- In existing research available on vulnerability assessment due to floods, mostly empirical studies are used. Statistical based study for the assessment was always lacking. The derived vulnerability functions are based on the observed damage level, material properties & structural properties, etc. The damage level is correlated with the structural damages in a probabilistic manner to derive vulnerability curves. The damageability primarily depended on the water depth and structural system. The final derived map is a vulnerability map which can be used for potential risk. So the study is first of its kind for flood vulnerability assessment.

- I have used Dr Naveed's model and results, which were employed for assessment in Punjab under the NDMA MHVRA project funded by World Bank. In KPK no such assessment existed. The vulnerability functions and score are directly obtained from the NDMA MHVRA project. The derived vulnerability functions were derived on the basis of data collected from the field and statistical analysis used to correlate structural damage level with the water depth. These vulnerability curves were further analyzed under the MHVRA project to devise vulnerability score for building stock.

Chapter3

RESEARCH METHODOLOGY

This chapter includes the research methodology, sampling, data collection, data analysis, research questions related to the study and the expected research design.

3.1. Basic Procedure

In this study different qualitative techniques were considered in order to determine the physical vulnerability due to floods in study area. Same were used to make qualitative risk assessment map for study area. For this purpose, the research was divided into three main parts which were: 1) pre-field research, 2) field research and 3) post-field. Taking 2010 floods as bench mark and elevation from Mean Sea Level (MSL), the selected areas of Seismandi and Kanderi (covering an area of 10.4 km) were divided into four polygons. The following steps were taken in order to obtain and assess the data:

3.1.1. Sampling/data collection& Building inventory through Google Earth & Arc GIS

3.1.1.1. Importing Digitized Grid Map

Digitized grid map was imported to Google Earth. Google Earth provides free Low resolution satellite images online. Careful observation of attributes in each grid was carried out. Observed data was stored in manual data base form. Each grid was separately marked with graded codes to differentiate Between built and non-built area. A sample of grid imported to Google Earth is shown in Figure .4.2

3.1.1.2. Sampling

Sample grid cells of each size of grids were created immediately after that. Sample grids comprised of satellite most possible zoomed view of various classes of buildings. These samples were used for observations of other grids. Sample grids were validated with actual site conditions. For identification of housing typologies at various parts of the study area, field observations through questionnaire at randomly selected places were carried out. Field observations consist of author's physical visit to some random places of study area and a greater part of such observations were covered using Google earth images. The housing type in a particular cell was compared with the Standard Template Cells (STC's). 19 STC's consists of various template grids obtained as a result of zooming in various grid cells and differentiating types of buildings, construction material, density, structural details, nature of construction etc. A sample of STC is shown in Figure 3.7.

3.1.1.3. Separating Built and Non built up Area

Through carful observations using sample grids unbuilt area was initially targeted in each progressive grid. As the study area contains different details, uninhabited areas are gradually excluded by the most possible clear zooming of each grid from ground. The iterative process enabled to develop the map shown in Figure 3.6, showing built up and non-built up areas with built up in transparent grids and non-built up marked in blue grids.

3.1.1.4. Categorization of Final Data

By comparison of the built up area under each transparent 100x100 sq m grid, the typology of the buildings in various locations were categorized and carefully noted.

3.1.1.5. Visual Comparison of Grid Cells with Standard template cells

In each zone (study area being divided into four zones), the transparent grids (built up area) were compared with Standard Template Cells from directory of 19 Standard template cells. In this way the number and types of buildings for each zone were determined by visual comparison of the cells with the standard template cells and counting it. In this way the number of houses relating to different standard template cells for the entire province was categorized. This has resulted into the development of the final building inventory for the entire area of responsibility to be used further incorporating elevation from mean sea level for Qualitative risk assessment.

3.1.1.6. Flow chart explaining the work methodology

The above steps are summarized in flow diagram Figure 3.1 for development of the building inventory for a test area. Building inventory is verified through on field visits / random sampling through questionnaire. Same could be verified through senses record for larger areas which includes large / complete union councils (minimum). Study area in our case was too small (10.4 sq km) and the area was not included as complete union council in its complete entirety to be verified through senses record.

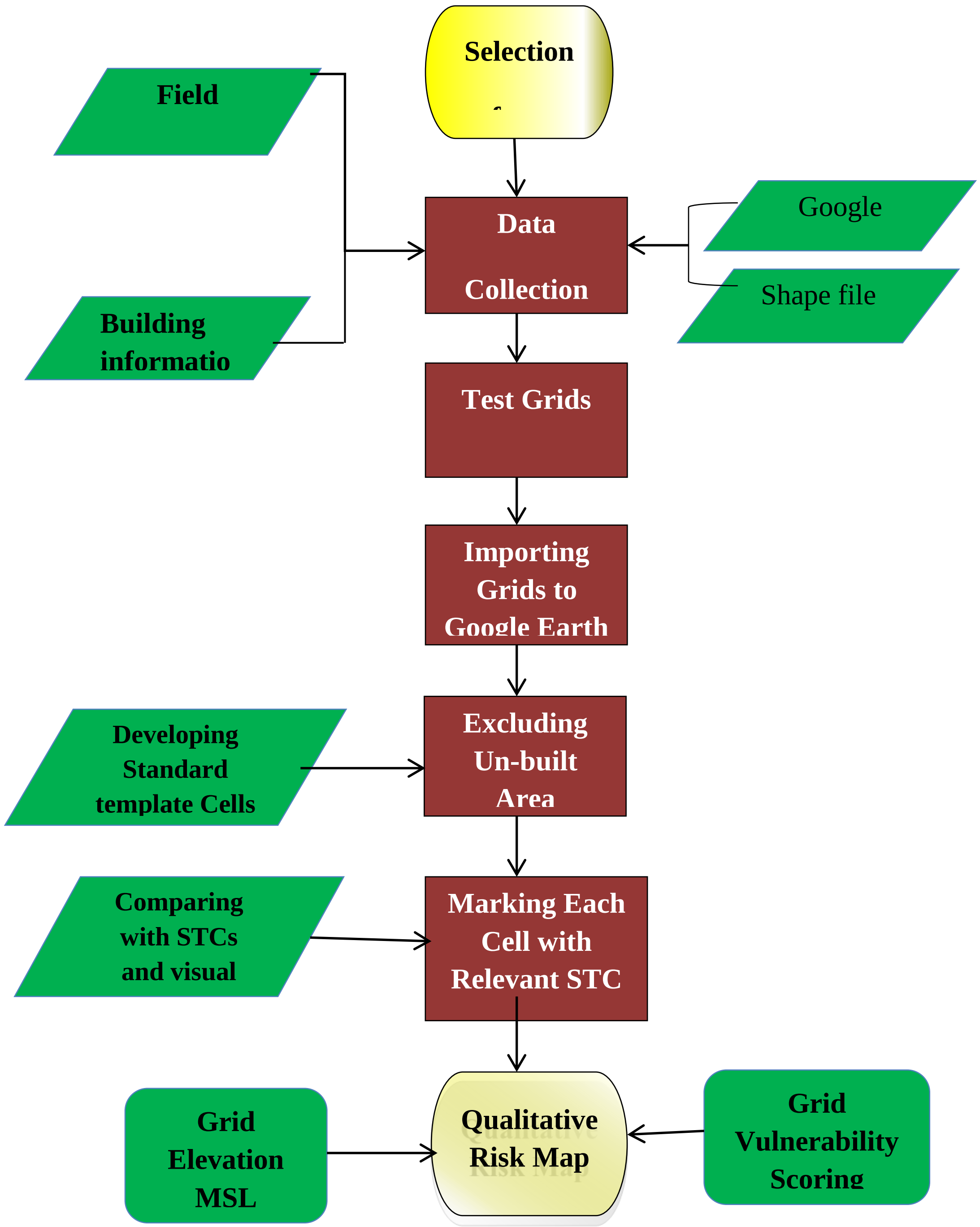

Figure 3.1: Conceptual frameworks in development of Building Inventory (process outline)

3.1.2. Vulnerability Scores and Mapping of area

Vulnerability scoring of each building typologies were used corresponding to the damageability of buildings. The vulnerability scoring is a qualitative index that, for a given hazard like flood in our case, can be used to quantify the relative vulnerability of buildings as per its types for subsequent development of vulnerability and risk map for that area. Table 3.1 shows the vulnerability scoring for the considered building typologies for Punjab at Provincial, District and UC levels. Same scores are being used by PDMA Punjab for development of vulnerability maps. These vulnerability scores are derived from vulnerability functions used in NDMA report prepared by Dr Naveed Ahmad from UET Peshawar who was the project director of ADB funded report. The vulnerability scores are based on vulnerability functions derived for The report presents exposure and vulnerability assessment for Punjab Province in Pakistan, as a pilot project under the Multi Hazards, Vulnerability and Risk Assessment (MHVRA) project of National Disaster Management Authority (NDMA) Pakistan. The report includes characterization of exposure (elements at risk), vulnerability assessment of physical structures & infrastructures and also social vulnerability of community. The project director was Dr Naveed Ahmad was physically interviewed for during multiple visits to UET Peshawar who has assisted in using the vulnerability scores as per our building typologies in our areas of study to derive maps which can be used to understand the spatial pattern of vulnerabilities in the subject area.(Ahmad et al., 2016)

Table 3.1: Building vulnerability scores for floods, Source:(Ahmad et al., 2016)

Ser No.	**Building Types**	**Vulnerability Scoring For Floods**
1	Reinforced Concrete	2.5
2	Stone Masonry	5.4
3	Mud/Adobe Masonry	7.14
4	Brick Masonry	3.66
5	Wood/Bamboo Traditional	4.82
6	Block Masonry	4.24
7	Others undefined	5

3.1.3. Step by step detailed procedure

Step 1: Convert kml file to shape Open arc map > search > kml to layer

Step 2: Add layer file to arc map.

Step 3: Creating grid Search> fishnet > give output destination > give input layer file > 100 * 100 sq. m

Step 4: Start editing and remove extra grids.

Step 5: Convert fishnet layer to KML

Step 6: Inspect all grids and give Id's to all grids. 0 Id represents built grids and 1 represents un-built grids.

Step 7: Add this excel file and merge with the existing attribute tables of shape file .Double click on that file. Layer properties>Symbology>Quantities>Field Value (select field Id) >Classes (2 classes) then give Blue color to 1 ID grids i.e. Un-built grids and make 0 ID grid transparent.

Step 8: Convert this file to KML.

Double Click on the following Kmz files Step wise in order to identify the polygon which shows the boundary of study area.

Path Measure (1)	8/8/2017 9:40 PM	KMZ	1 KB
Path Measure (2)	8/8/2017 9:40 PM	KMZ	1 KB
Path Measure (3)	8/8/2017 9:40 PM	KMZ	1 KB
Polygon Measure	8/8/2017 9:40 PM	KMZ	2 KB

Figure 3.2: Step by step procedure, Google earth and Arc GIS -Boundary of study area

After opening all these files we get the resultant polygon enclosing the study area in Google earth Pro as shown in the Figure.

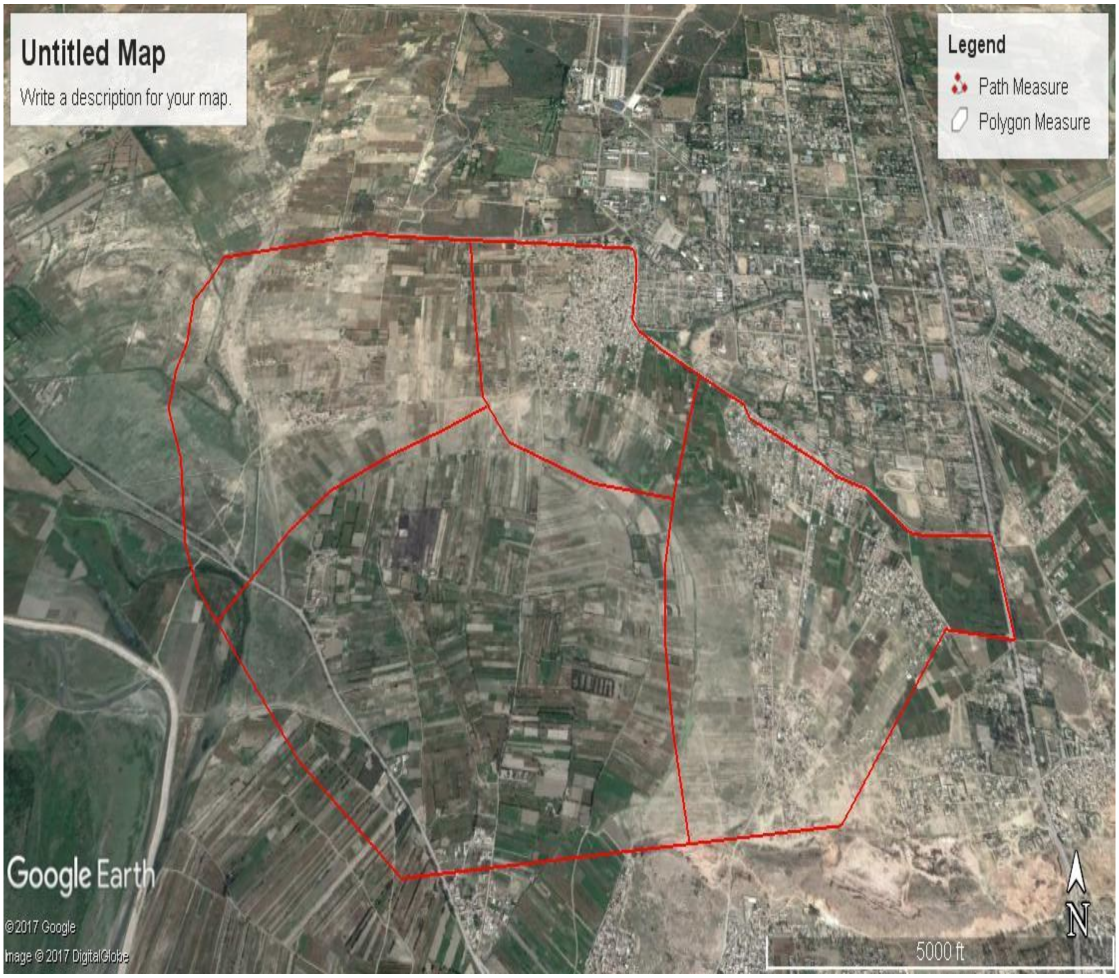

Figure 3.3: Google earth image with Boundary of study area marked

Step 9: Open the Kmz file of the layer containing Grids. The file is as shown in the Figure below.

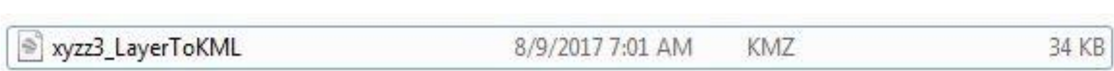

Figure 3.4: Step by step procedure, Google earth and Arc GIS – Grid marking

Opening this file give the following result.

Figure 3.5: Template grid of size 100m sq. incorporated to Google Earth

Step 10: Open the kmz file of the layer in which built and un-built areas have been separated in Arc GIS.

As we have to deal with the built areas only so excluding the un-built. The result is shown in the Figure.

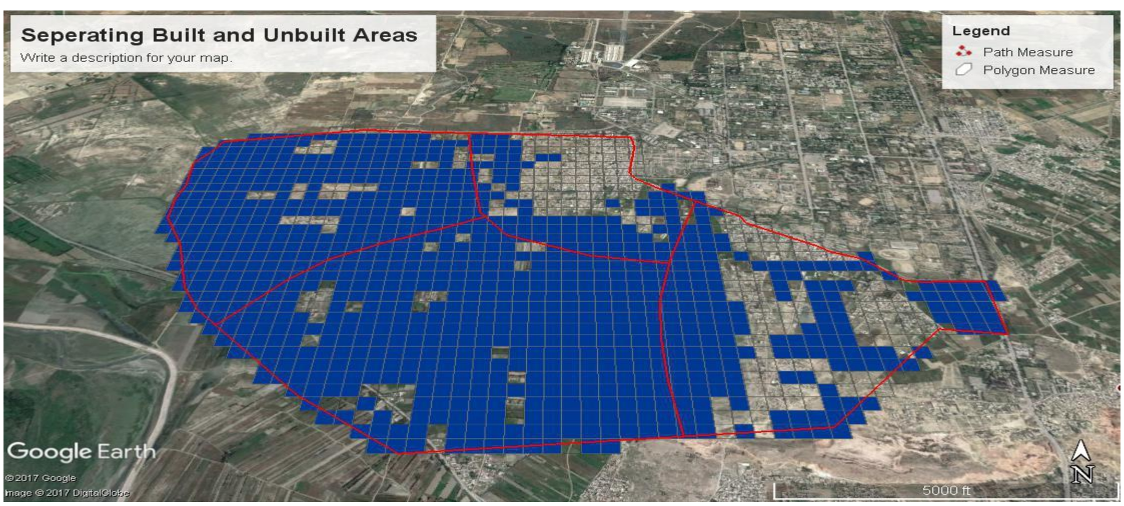

Figure 3.6: Eliminating Built and non-built up areas

Step 11: Selection of Standard template Cells (STC, s) for Building Inventory.

Standard template cell (STC) technique is used for finding the number of buildings and typology of building in the study region.

Standard template cell is a grid selected from the study region in which the number of buildings are counted and the typology is noted that in this particular grid what is the total number of buildings and what are their types .For example if in the STC there are 8 RCI structures and it's FID in Google earth is 3, Then look for Similar grids Containing 8 RCI structures in all the built grids and in excel sheet of the study area make a new column with the name Typology with respect to STC and write RCI3 in front of all such grids .3RCI means the buildings are RCI and the FID is 3.

Total 19 STCs were selected and for each STC we have to go through all the grids and check if there is any other grid similar to STC. If we check any Grid in the study area then it will be similar to any of the 19 STC, s.

Example: RCI3 STC

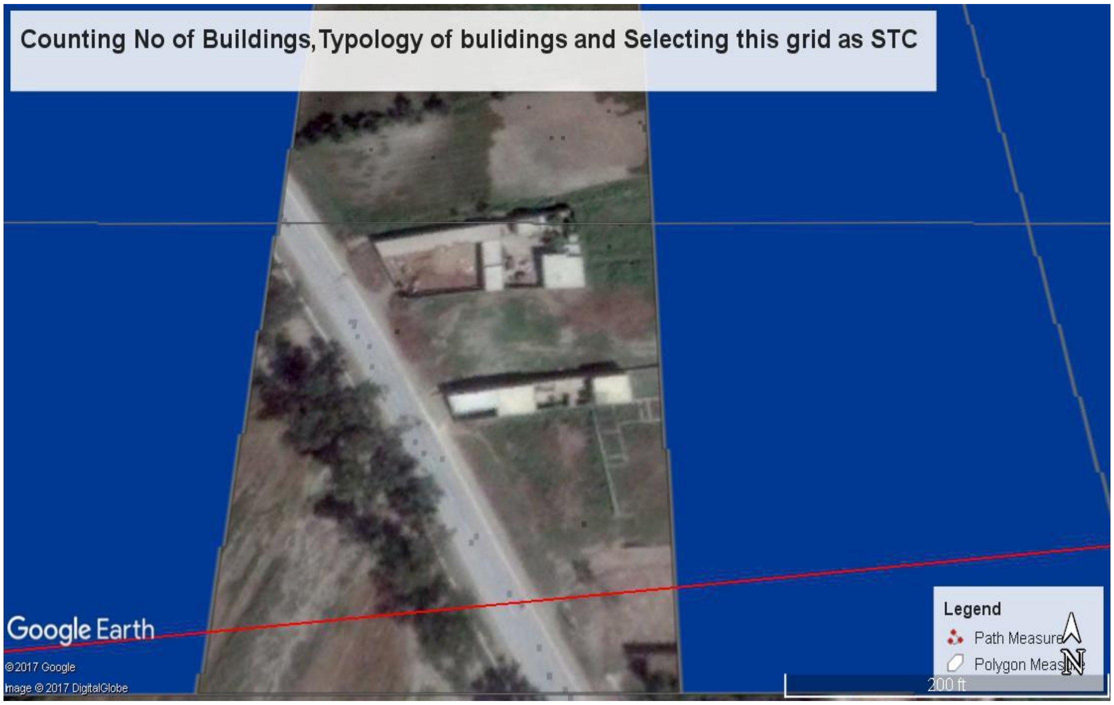

Figure 3.7: Differentiating various Building Classes

Once All the grids are covered with their Stc,s refrence written in excel then add 5 Typologies columns in the same excel Sheet with the name ,RCI,RCF,UBM-CM,UBM-MM and Adobe and in front of the Stc,s Refrence write the No of buildings in the correspoinding typology column and zero in the remaining column.

FID	SHAPE *	ID	TYPOLOGY WITH RESPECT TO STC	RCF	RCI	UBM -CM	UBM-MM	ADOBE
464	Point	0	UBM CM 915	0	0	12	0	0
465	Point	0	UBM CM 126	0	0	40	0	0
466	Point	0	UBM CM 195	0	0	25	0	0
467	Point	1	Exclude	0	0	0	0	0
468	Point	0	UBM CM 195	0	0	25	0	0
469	Point	1	Exclude	0	0	0	0	0
470	Point	1	Exclude	0	0	0	0	0
471	Point	0	RCF 79	2	0	0	0	0
472	Point	0	RCF + RCI 341	3	4	0	0	0
473	Point	0	RCF 473	6	0	0	0	0
474	Point	0	RCI 3	0	8	0	0	0
475	Point	1	Exclude	0	0	0	0	0
476	Point	1	Exclude	0	0	0	0	0
477	Point	1	Exclude	0	0	0	0	0
478	Point	1	Exclude	0	0	0	0	0
479	Point	1	Exclude	0	0	0	0	0
480	Point	1	Exclude	0	0	0	0	0
511	Point	1	Exclude	0	0	0	0	0
512	Point	1	Exclude	0	0	0	0	0
513	Point	1	Exclude	0	0	0	0	0
514	Point	1	Exclude	0	0	0	0	0
515	Point	0	UBM CM 915	0	0	12	0	0
516	Point	0	RCI + UBM CM 801	0	0	0	0	0
517	Point	0	UBM CM 915	0	0	12	0	0

Figure 3.8: Excel Sheet Showing STC s refrence and typologies.Exclude means Un-built Grid

In this way total Number of buildings in all the four zones have been calculated and the results are then plotted Zone Wise.

Step 12. Find vulnerability Scores of all types of buildings in a grid and add them to get Vulnerability score for the grid as a whole.Using the Table 1 for Vulnerability of diifferent types of buildings.The Data Sheet of Vulnerability Score Calculations is shown in the Figure.

FID	SHAPE *	ID	TYPOLOGY WRT STC	RCF	RCI	UBM -CM	UBM-MM	ADOBE	2.5 RCF	2.5 RCI	3.66 UBM-CM	7.14 *UBM-MM	7.14*Adobe	Grid Vulnerability Score (K+L+M+N+0)
0	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
1	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
2	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
3	Point	0	RCI 3	0	8	0	0	0	0	20	0	0	0	20
4	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
5	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
6	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
7	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
8	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
9	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
10	Point	0	Exclude	0	0	0	0	0	0	0	0	0	0	0
11	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
12	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
13	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
14	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
15	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
16	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
17	Point	0	Exclude	0	0	0	0	0	0	0	0	0	0	0
18	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
19	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
20	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
21	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0
22	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0

Figure 3.9: Excel Sheet Showing STC s refrence and typologies with grid vulnerability scores

Step 13: Grid Elevation. To find the grid elevation make sure that terrain layer in Google earth Pro is ticked then bring the cursor to the midpoint of the grid without clicking on the grid, the elevation of that grid automatically appears on the right bottom side of Google Pro as shown in the image below.

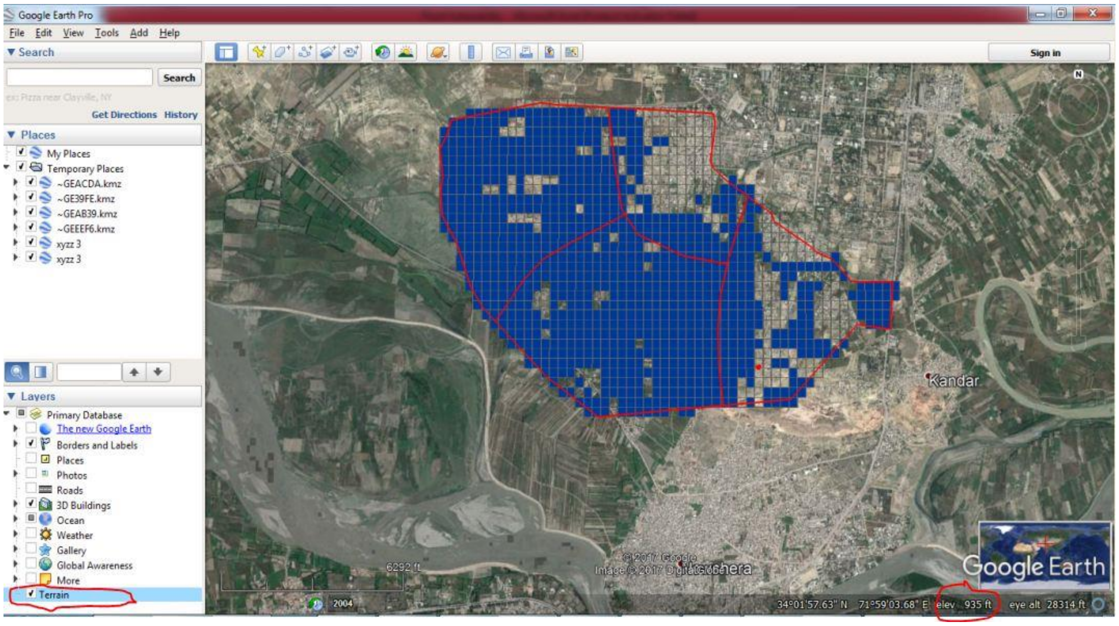

Figure 3.10: Google image showing elevation levels with terrain layer checked

In the similar manner find the elevation of each grid (FID) and write it in Excel Sheet in corresponding FID row as shown in Figure Below.

FID	SHAPE *	ID	TYPOLOGY WRT STC	RCF	RCI	UBM -CM	UBM-MM	ADOBE	2.5 RCF	2.5 RCI	3.66 UBM-CM	7.14 *UBM-MM	7.14*Adobe	Grid Vulnerability Score (K+L+M+N+O)	Elevation
0	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	946
1	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	944
2	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945
3	Point	0	RCI 3	0	8	0	0	0	0	20	0	0	0	20	946
4	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943
5	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	940
6	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942
7	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943
8	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943
9	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945
10	Point	0	Exclude	0	0	0	0	0	0	0	0	0	0	0	946
11	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943
12	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942
13	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945
14	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	944
15	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943
16	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942
17	Point	0	Exclude	0	0	0	0	0	0	0	0	0	0	0	942
18	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942
19	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	939
20	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	944
21	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	948
22	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945

Figure 3.11 Excel: Sheet with grid vulnerability scores & elevation incorporated

Step 14. Resultant Vulnerability Score for Each Grid

Divide the grid vulnerability by elevation to get resultant flood vulnerability score for each grid.

But for plotting a map we will convert all the resultant vulnerability scores into a range of 0-10

In order to convert all the values into a fix range we use normalization technique.

Step 15. Normalization

Find the highest value in the resultant flood vulnerability score COLUMN which is 0.28 and divide this max value by 10 we get 0.028 .(Dividing max value by 10 b/c Upper limit in our range is 10) After this divide the resultant flood vulnerability values by 0.028 so all the values are converted into a range of 0-10.

The Calculation Sheet of Flood resultant vulnerability score is as shown in the Figure below.

S2 | f_x =R2/0.028

FID	SHAPE *	ID	TYPOLOGY WRT STC	RCF	RCI	UBM -CM	UBM-MM	ADOBE	2.5 RCF	2.5 RCI	3.66 UBM-CM	7.14 *UBM-MM	7.14*Adobe	Grid Vulnerability Score (K+L+M+N+O)	Elevation	Grid Vulnerability	Grid Resultant Vulnerability Score
0	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	946	0.000	0.000
1	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	944	0.000	0.000
2	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945	0.000	0.000
3	Point	0	RCI 3	0	8	0	0	0	0	20	0	0	0	20	946	0.021	0.755
4	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943	0.000	0.000
5	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	940	0.000	0.000
6	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942	0.000	0.000
7	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943	0.000	0.000
8	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943	0.000	0.000
9	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945	0.000	0.000
10	Point	0	Exclude	0	0	0	0	0	0	0	0	0	0	0	946	0.000	0.000
11	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943	0.000	0.000
12	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942	0.000	0.000
13	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	945	0.000	0.000
14	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	944	0.000	0.000
15	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	943	0.000	0.000
16	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942	0.000	0.000
17	Point	0	Exclude	0	0	0	0	0	0	0	0	0	0	0	942	0.000	0.000
18	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	942	0.000	0.000
19	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	939	0.000	0.000
20	Point	1	Exclude	0	0	0	0	0	0	0	0	0	0	0	944	0.000	0.000

Figure 3.12: Excel Sheet Showing Grid resultant vulnerability score after normalisation

Step: Import the above excel file to Arc Map and update the attribute file of the layer by adding the vulnerability flood column of the imported excel file. Right Click on layer > Layer Properties > Symbology > Quantities>Field values>Grid resultant Vulnerability > Classes > 6 > Colurramp > Ist Color Range Double Click > 0> oK

The method of random sampling was used later for verification of results of secondary data. Different samples were collected from different regions of the selected areas. The approximate numbers of buildings are 5200 as per working .As observing the whole area could be complicated so only 8 percent of the selected areas were observed in order to sample the required data. For the questionnaire survey, 402 households were targeted. In order to record the elevation of each structure from the MSL, the 'Compass-55 application' was used as the GPS. For the risk assessment, each building's geographical location was needed to be determined along with the use of risk map using the GPS. The pictorial evidence was also used to support the samples collected by using this method.

3.2. Data Collection through Questionnaire

It was considered important to involve the people of the affected areas in order to determine the risk elements of the specific areas. So for this purpose, both quantitative as well qualitative studies were done. The information obtained on 'the flood depth, damage and duration' is considered as the important factor of the field work which is considered as the essence of the research study. While the formation of the questionnaire along with the division of the selected areas into four zones; is known as the pre-field work.

Primary data was collected through the questionnaire as per stated objectives for vulnerability assessment and qualitative risk assessment/calculation of building stock. Its purpose was to find the element at risk and flood depth and duration and the level of damage to selected building stock. Secondary data collection though google earth pro for creation of building inventory was subsequently verified through questionnaire by on field survey and asking relevant questions. Questionnaire data was also validated through DDMU Nowshera for verification of 2010 flood losses.

Chapter 4

RESULTS AND ANALYSIS

This chapter includes the Results and Analysis. To obtain the results of the collected data, arc GIS and SPSS along with MS excel was mostly used and following results were derived.

4.1. Results and Analysis:

4.1.1. Types of buildings in the Study Area.

Following types of building were found in selected area after field survey.

4.1.1. Reinforced Concrete Framed (Structure type I)

Reinforced concrete frames were found as commercial units mostly. Their height varies from 3-4 stories, however majority of such types of buildings were 2-3 stories. These buildings have strong resistance against floods in general (Figure 4.1). Due to high cost of construction, RCF were not very commonly used in the areas of research. Mostly commercial buildings are constructed in RCF type.

Figure 4.1: Reinforced Concrete Framed (Structure type I)**,** Source : field work

4.1.2. Reinforced Concrete Frame with infill masonry (Structure type II)

Reinforced concrete with masonry infill exists in large numbers in urban areas. These buildings may consist of 3 to 4 stories but in study area mostly these were 2 storied. Mostly buildings are non-engineered and relatively vulnerable to the RCF due to poor quality of construction and materials use. (Figure 4.2). The flood performance of the RCI buildings is normally below the standards.

Figure 4.2: Reinforced Concrete Frame with infill masonry (Structure type II), Source: field work

4.1.3. Un-Reinforced Brick Masonry- Cement Mortar (Structure type III)

These types of buildings are more common in study area for residential usage. Brick Masonry with cement and sand mortar is used for these type of buildings. Such type of buildings re maximum up to 3 stories with RCC roofing. These building are more vulnerable to flood damages. (Figure 4.3).

Figure 4.3: Un-Reinforced Brick Masonry- Cement Mortar (Structure type III), Source: field work

4.1.4. Un-Reinforced Brick Masonry- Mud Mortar (Structure type IV)

These building types are more common in study region for residential usages. Brick Masonry with Mud mortar (MM) is used for this type of buildings. Such types of buildings are single stories with timber and girder roofing. (Figure 4.4). This type of buildings again is more vulnerable to floods and its associated damages.

Figure 4.4: Un-Reinforced Brick Masonry- Mud Mortar (Structure type IV), Source: field work

4.1.5. Adobe Structures or Mud Wall Structures (Structure type V)

These are low cost buildings incorporating local material and expertise. Such type of buildings predominantly exist in rural areas or may be non-residential deras while as scarcely in urban areas as well. Construction comprises of mud walls i.e. mud bricks with mud mortar for binding with Timber roofing, or girder roofing. (Figure 4.5) The nature of major damages to adobe houses in Pakistan during 2010 floods has been pronounced.

Figure 4.5: Adobe Structures or Mud Wall Structures (Structure type V), Source: field work

4.2. Results of building inventory in different zones:

Results of step by step data collection using Raster google image and arc GIS and its ultimate development into building inventory into 4 different zones is graphically shown underneath.

Zone IV is concluded to have total of 95 structures with mostly RCI, preceded by UBM-CM category then RCF and there are only 6 adobe structures in zone IV.

Zone Name	RCF	RCI	UBM-CM	UBM-MM	ADOBE	TOTAL BUILDIGS IN ZONE
Zone 4	15	34	32	8	6	95

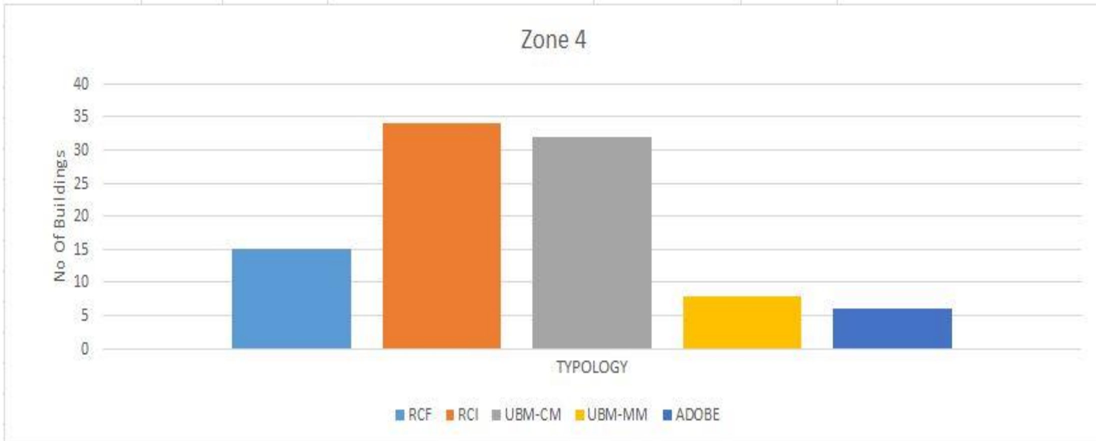

Figure 4.6: Building types in zone IV, Source: Research work

Siesmandi area have total of 1840 structures. Most of the structures are UBM-CM preceded by RCI than RCF and there are very few UBM-MM and adobe structures as well.

Zone Name	RCF	RCI	UBM-CM	UBM-MM	ADOBE	Total Buildings in Zone
Seismandi	102	125	1606	3	4	1840

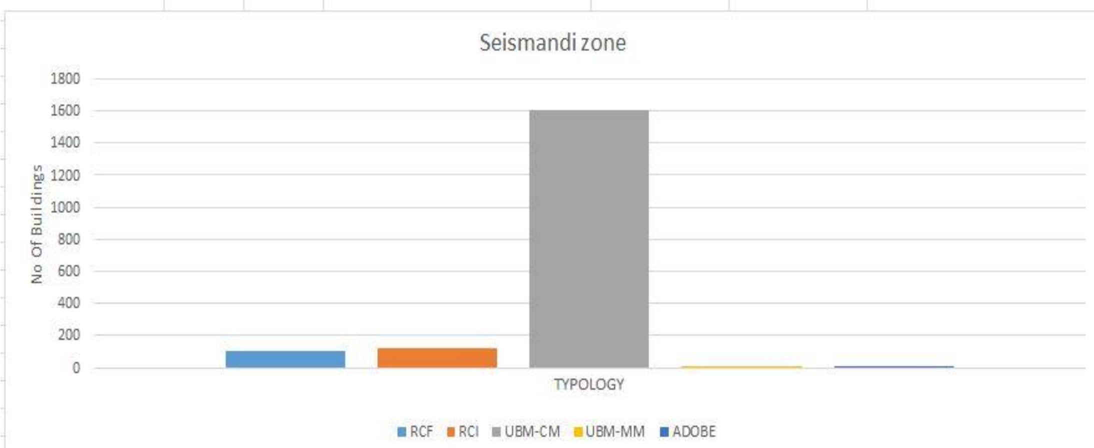

Figure 4.7: Building types in Siesmandi, Source: Research work

Zone III contains mostly UBM-CM structures while there are a few RCI and some RCF structures as well.

Zone Name	RCF	RCI	UBM-CM	UBM-MM	ADOBE	Total Buildings in Zone
Zone 3	4	21	500	0	0	525

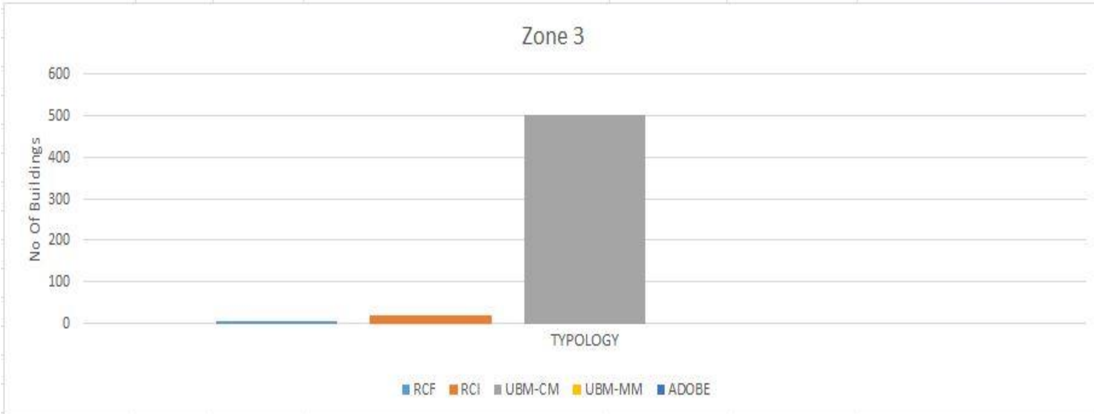

Figure 4.8: Building types in Zone III, Source: Research work

Kanderi area contain mostly UBM-CM structures. This is the most populated area inside the study area. It contains all types of identified structures with a little percentage of Adobe and some UBM-MM also included in identified structures. Here too most of the structures are UBM-CM preceding RCI structures and then the RCF type of structures identified in study area.

Zone Name	RCF	RCI	UBM-CM	UBM-MM	ADOBE	Total Buildings in Zone
Kanderi	77	101	2513	27	22	2740

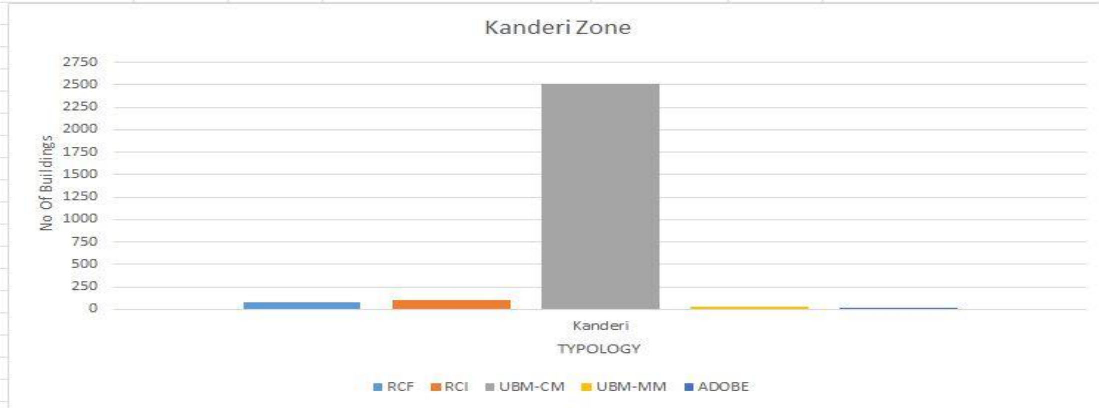

Figure 4.9: Building types in Kanderi, Source: Research work

4.3. Summary of structural types in study area

Summary of the all five identified structural types in the study area is shown in graph… UBM- CM are the most available structures in all 4 zones and adobe structures are the least identified structures inside the study area. Although RCI and RCF structures are also available in all zones. Both structures are used for commercial purposed (identified during field survey through questionnaire)

Zones	RCF	RCI	UBM-CM	UBM-MM	ADOBE	TOTAL BUILDIGS IN EACH ZONE
Zone 4	15	34	32	8	6	95
Seismandi	102	125	1606	3	4	1840
Zone 3	4	21	500	0	0	525
Kanderi	77	101	2513	27	22	2740
						5200

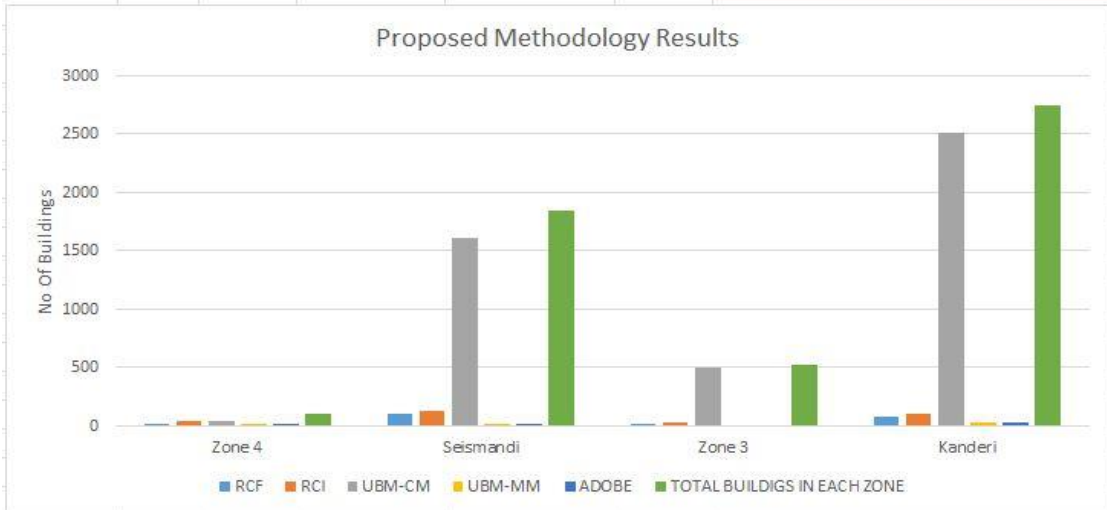

Figure 4.10: Total Buildings and types in study area, Source: Research work

After all types of buildings are identified in the study area, the building vulnerability scores as mentioned in table 1(Ahmad et al., 2016) are used for each grid. Taking number of buildings in each grid and using elevation from mean sea level a grid vulnerability for each grid is calculated. Using normalization technique all vulnerable structures are brought into the range of 0-10 with non-built up area shown as o depicting material vulnerability as Nil. Importing the excel file to Arc Map and updating the attribute file of the layer by adding the vulnerability flood column of the imported excel file resultant Qualitative Risk map of floods for physical vulnerability is obtained as shown in Figure 2 with physical vulnerability ranging into 6 categories as shown.

4.4. Vulnerability Map of the Area:

Vulnerability Map

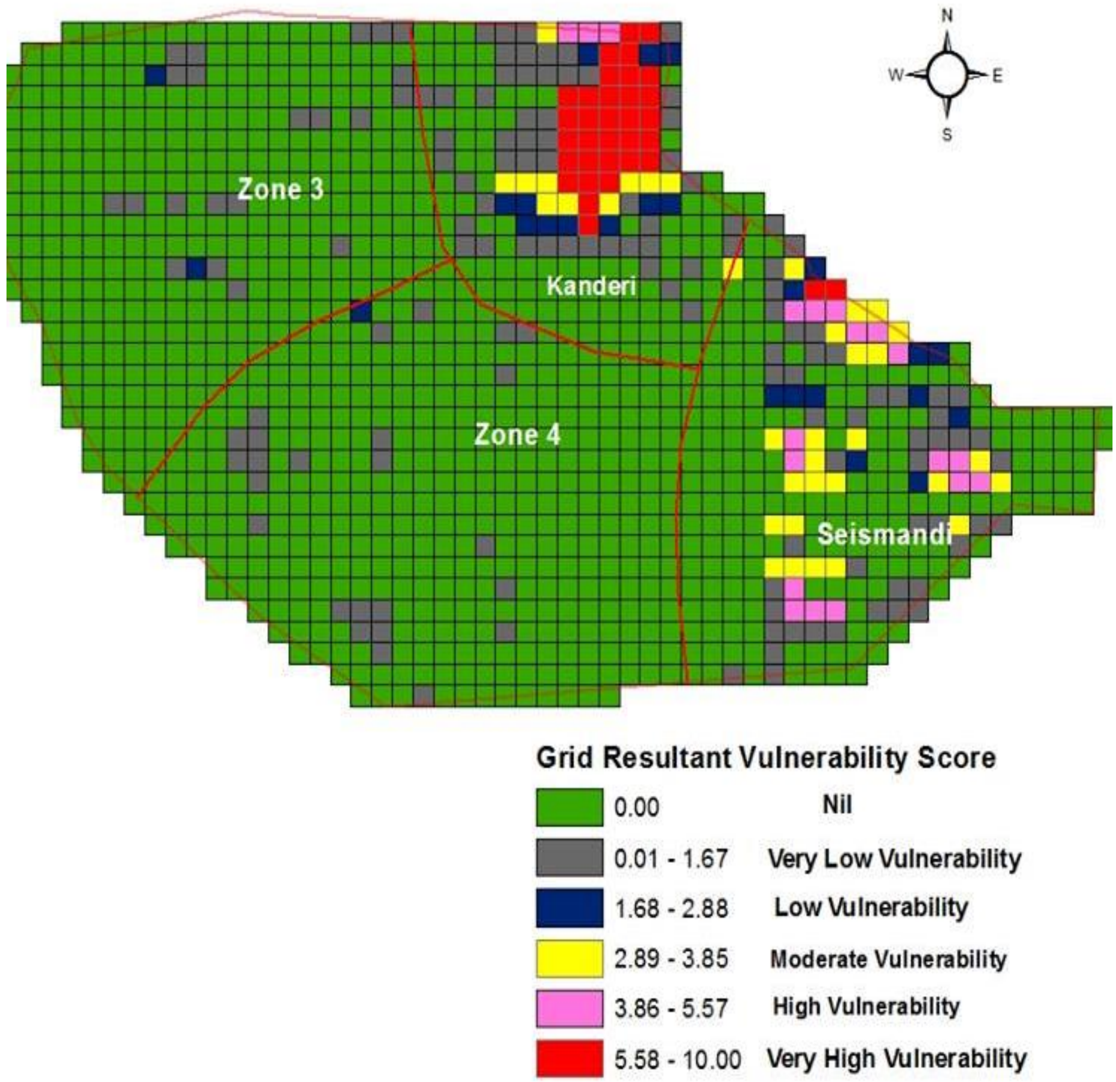

Figure 4.11: Vulnerability Map with Resultant grid vulnerability scores, Source: Research work

4.5. Details of the physical survey through questionnaire

4.5.1. Location

Table 4.1: Location of Buildings in each zone, Source: physical survey

Building Locations	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Seismandi	129	32.1	32.1	32.1
Kanderi	127	31.6	31.6	63.7
Zone III	87	21.6	21.6	85.3
Zone IV	59	14.7	14.7	100.0
Total	402	100.0	100.0	

Most data (i.e. 32.1percent) was collected from Seismandi, as this area was thickly populated. 2nd most populated area was Kanderi so accordingly proportionate sample was selected for this area. Zone 3 & 4 were scarcely populated so represents proportionate percentage of the sample collection.

4.5.2. Construction year

Table 4.2: Construction year of Buildings in each zone, Source: physical survey

Building Construction year	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Between 2010-2017	68	16.9	16.9	16.9
Between 1998-2010	166	41.3	41.3	58.2
Between 1985-1998	67	16.7	16.7	74.9
Before 1985	101	25.1	25.1	100.0
Total	402	100.0	100.0	

From table 4.2, it was concluded that the surveyed buildings (i.e. 41.3 percent), were constructed in years from 1998 to 2010. 25.1 percent buildings were constructed in 1985. However surveyed buildings constructed from 2010 to 2017 and from 1985 to 1998 were of 16.9 percent and 16.7 percent respectively.

4.5.3. Ownership

Table 4.3: Ownership of Buildings, Source: physical survey

Building Ownership	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Own	275	68.4	68.4	68.4
Rent	127	31.6	31.6	100.0
Total	402	100.0	100.0	

Table 4.3, concludes that out of surveyed buildings 68.4 percent were owned by residents while 31.6 were rented out by the residents to be used by others.

4.5.4. Utility

Table 4.4: Utility of Buildings, Source: physical survey

Building Utility	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Commercial	108	26.9	26.9	26.9
Residential	251	62.4	62.4	89.3
Education	15	3.7	3.7	93.0
Mosque	11	2.7	2.7	95.8
Health	17	4.2	4.2	100.0
Total	402	100.0	100.0	

Table 4.4, concludes that out of the surveyed buildings 26.9 percent were commercially used, 62.4 percent were used for residential purposes. While education, religious and health purpose surveyed buildings were less than 5 percent.

4.5.5. Foundation Depth

Table 4.5: Foundation depth in Buildings, Source: physical survey

Foundation Depth	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
1 ft	42	10.4	10.4	10.4
2 ft	90	22.4	22.4	32.8
3 ft	209	52.0	52.0	84.8
Greater than 3 ft	61	15.2	15.2	100.0
Total	402	100.0	100.0	

Table 4.5, concludes that out to the surveyed buildings 10.4 percent had 1 ft foundation depth, 22.4 had 2 ft foundation depth, 52 percent had 3 ft of foundation, while 15 percent had more than 3 ft of foundation as confirmed by the residents

4.5.6. Foundation material

From Figure 4.12, it was concluded that the surveyed buildings that had the foundation made up of bricks were almost 69.4 percent, while 24.6 percent of the buildings that had a foundation made up of stones whereas 6 percent of the buildings had other materials that were used for the foundation of such buildings.

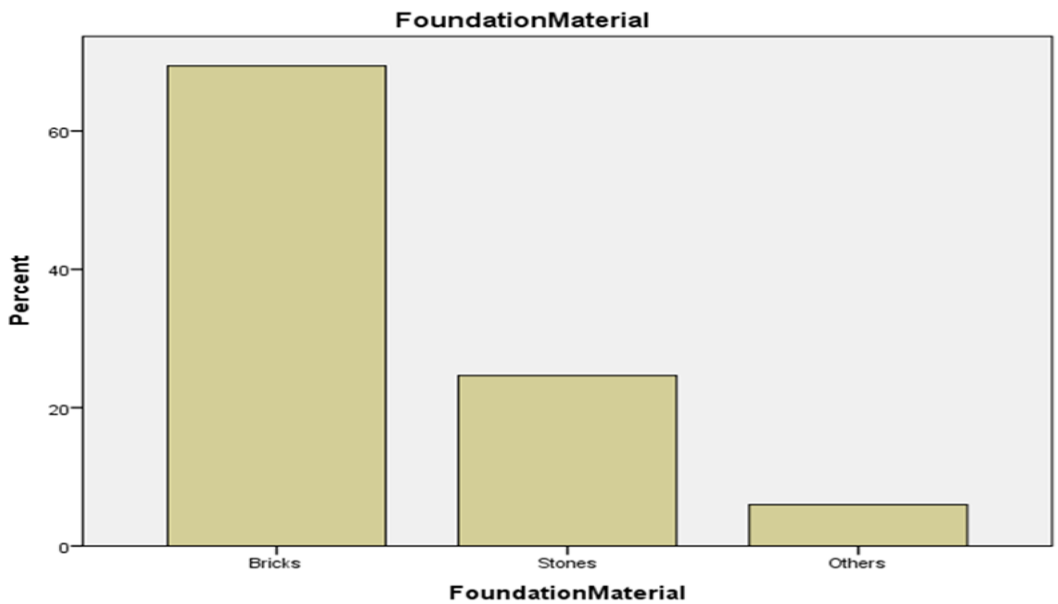

Figure 4.12: Material used in foundation of surveyed buildings, Source: field work

4.5.7. Wall material

From Figure 4.13, it was concluded that out of the surveyed buildings 60.4 percent had Brick walls, 20.6 percent had adobe or mud in walls as building unit, 4.7 had blocks while similar percentage had stones in walls as construction material, whereas 9.5 percent had mud walls

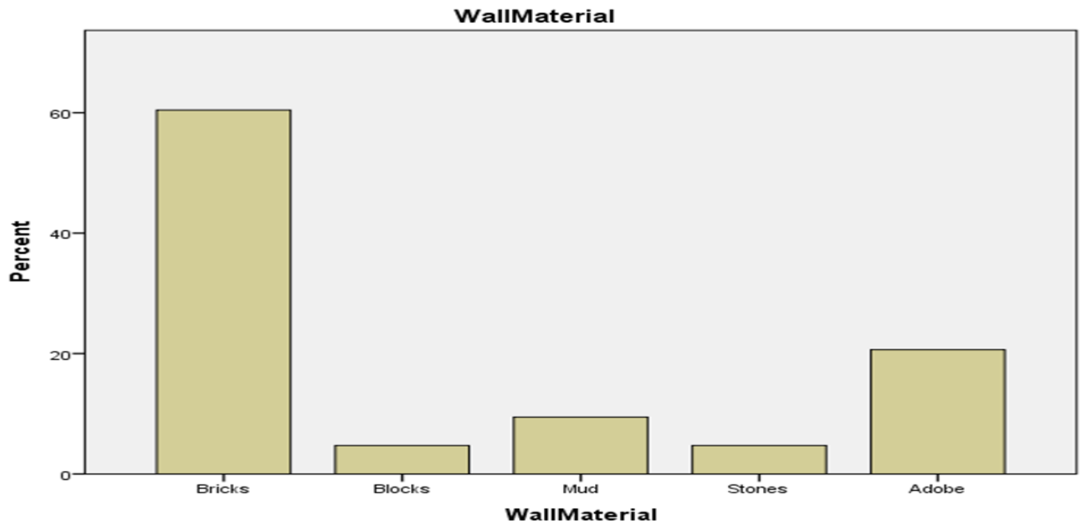

Figure 4.13: Material used in walls of surveyed buildings, Source: field work

4.5.8. Floor material

From Figure 4.14, it was concluded that 81.3 percent of the surveyed buildings which were affected by the floods had floors made up of PCC, bricks and tiles while 18.7 percent of the affected buildings had soil as their floor material.

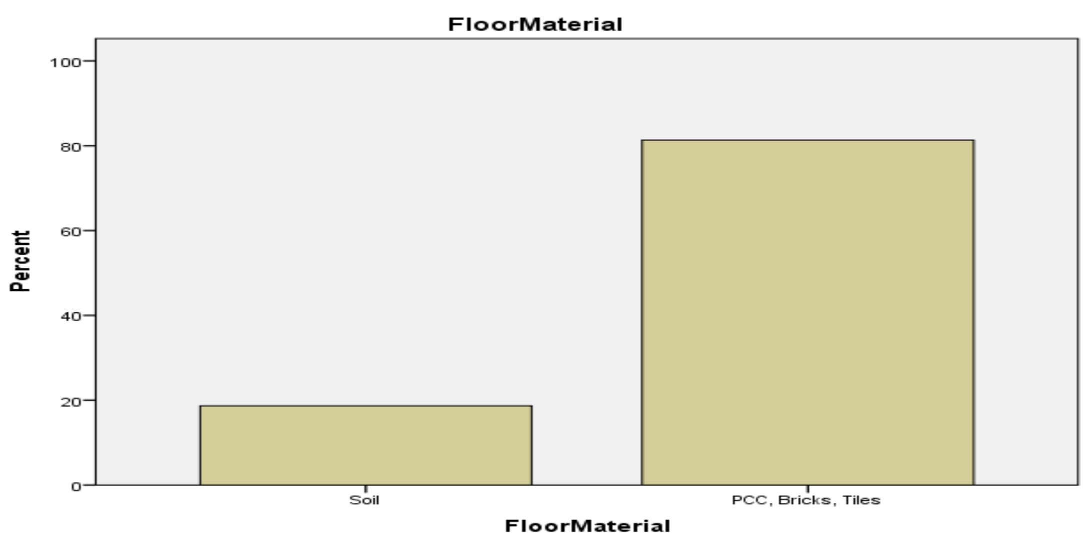

Figure 4.14: Material used in floor of surveyed buildings, Source: field work

4.5.9. Roof material

From Figure 4.15, it was concluded that 54.7 percent of the buildings that were affected by the floods had RCC as the roof material while 37.3 percent of the affected buildings had straw and wood as their roof material and 8 percent of the buildings had brick tiles as the roof material.

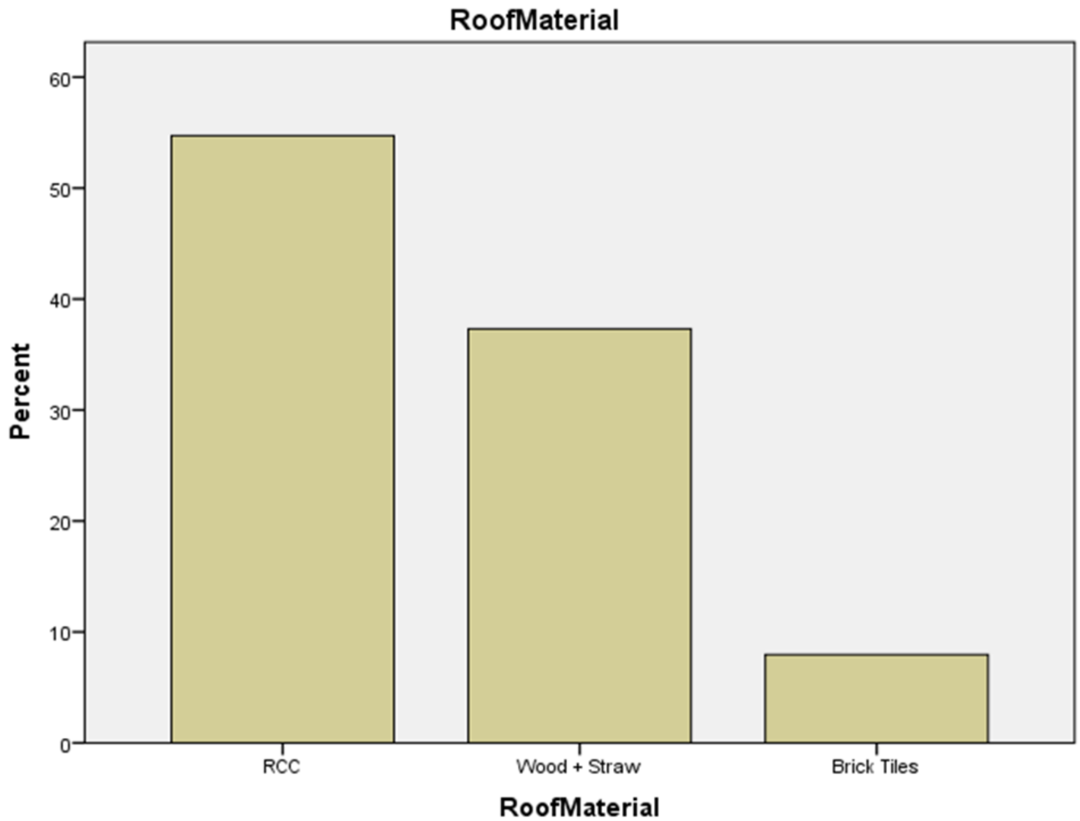

Figure 4.15: Material used in roofs of surveyed buildings, Source: field work

4.5.10. No. of Building Storeys

Table 4.6: No of storeys, Source: Field work

No of Storeys	Frequency	Percent	Valid Percent	Cumulative Percent
1	335	83.3	83.3	83.3
2	54	13.4	13.4	96.8
3	13	3.2	3.2	100.0
Total	402	100.0	100.0	

From table 4.5, it was concluded that 83.3 percent of the buildings which were affected by the floods were single storied while 13.2 percent of the affected buildings had 2 storeys and 3.2 percent of the buildings had 3 storeys.

4.5.11. Binder

Table 4.7: Binder used in construction, Source: Field work

Binder used in construction	Frequency	Percent	Valid Percent	Cumulative Percent
Clay	92	22.9	22.9	22.9
Cement Mortar	278	69.2	69.2	
Other	32	8.0	8.0	92.0
Total	402	100.0	100.0	100.0

From table 4.7, it was concluded that 22.9 percent of the surveyed buildings that were affected by the floods had clay as their binder material during construction while 69.2 percent of the affected buildings had cement as their binder during construction and 8 percent buildings had other binders.

4.5.12. Openings

Table 4.8: Openings used in construction, Source: Field work

Opening size	Frequency	Percent	Valid Percent	Cumulative Percent
Large Valid	77	19.2	19.2	19.2
Regular/Normal	325	80.8	80.8	100.0
Total	402	100.0	100.0	

From table 4.8, it was concluded that 80.8 percent of the buildings which were surveyed floods had regular and normal openings while 19.2 percent of the buildings that were affected by the buildings had large openings.

4.5.13. Opening location

Table 4.9: Opening location used in construction, Source: Field work

Window Level	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Windows Level	402	100.0	100.0	100.0

From table 4.9, it was concluded that all the buildings that were surveyed and were affected by the floods had valid windows level.

4.5.14. Type of flood

Table 4.10: Type of Flood encountered by occupants, Source: Field work

Type of Flood	Frequency	Percent	Valid Percent	Cumulative Percent
Low	40	10.0	10.0	10.0
Medium	218	54.2	54.2	64.2
High	144	35.8	35.8	100.0
Total	402	100.0	100.0	

From table 4.10, it was concluded that once occupants were asked about the severity of past floods, their description was that 54.2 percent buildings were affected by the medium type of flood while 10 percent buildings were damaged by low type of floods and 35.8 percent buildings were damaged by high type of floods. 2010 flood was considered most severe of the past floods.

4.5.15. Duration of flood

From Figure 4.16, it was concluded that in 50.7 percent of the surveyed buildings in the 2010, floods took place for about 48 hours while 33.6 percent of the buildings had 2010 flood took place for 72 hours. 9.2 percent of the buildings had 2010 flood taking place for more than 72 hours and 6.5 percent of the buildings had the flood taking place for 24 hours.

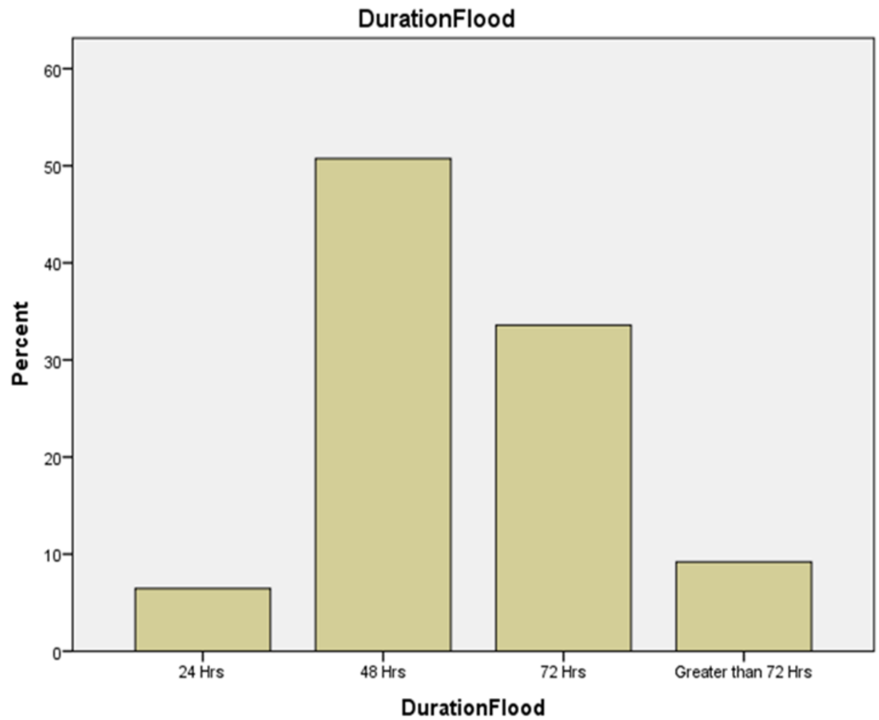

Figure 4.16: Duration of flood of surveyed buildings, Source: field work

4.5.16. Max water level

From Figure 4.17, it was concluded that in 49.8 percent of the surveyed buildings floods had a max water level of 5 to 10 feet while 30.1percent of the floods had a max water level up to 10 to 15 feet. 7 percent of the buildings had floods water level up to 0 to 5 feet whereas 13.2percent floods had a water level greater than 15 feet.

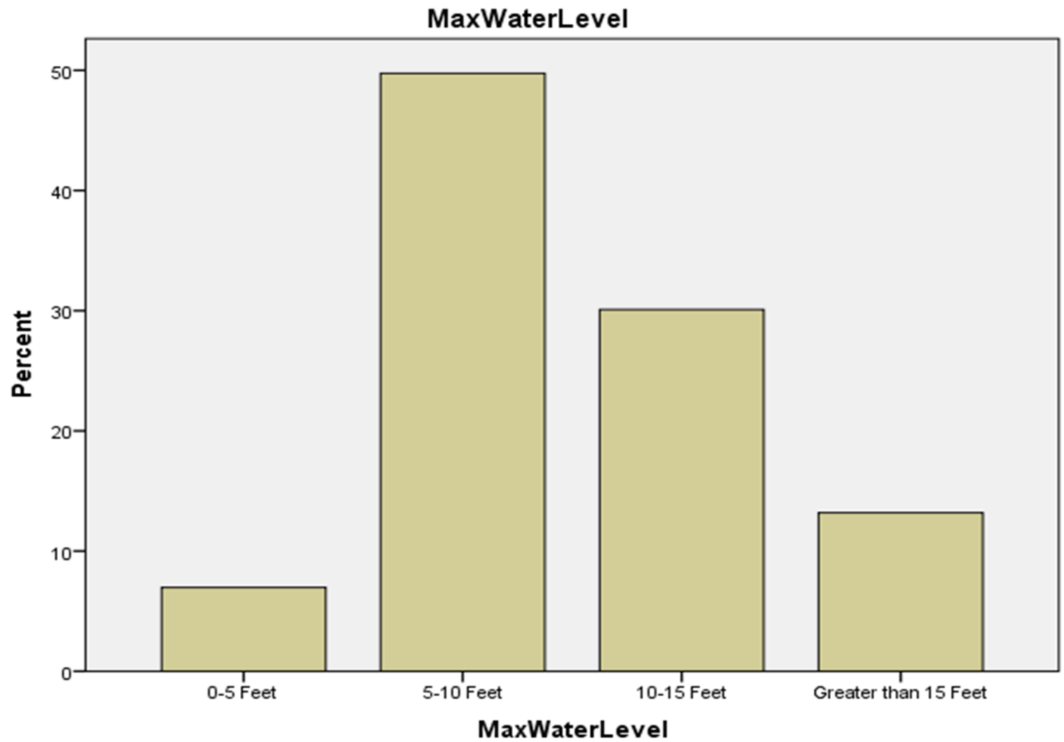

Figure 4.17: Maximum water level in flood of surveyed buildings, Source: field work

4.5.17. Foundation Damage

From table 4.11 and Figure 4.18 it was concluded that Kanderi was the worst affected as far as damage to the foundation due to 2010 floods is concerned, followed by Siesmandi, than zone-III and followed by zone-IV. Similar patterns of damage were observed for collapsed and half collapsed foundation structure.

Table 4.11: Foundation damage to surveyed buildings, Source: Field work

Foundation Damage Pattern		Location				Total
		Seismandi	Kanderi	Zone III	Zone IV	
Collapse	Count	4	8	1	0	13
	percent within Foundation Damage	30.8%	61.5%	7.7%	0.0%	100.0%
	percent within Location	3.1%	6.3%	1.1%	0.0%	3.2%
	percent of Total	1.0%	2.0%	0.2%	0.0%	3.2%
Half Collapsed	Count	5	7	4	3	19
	percent within Foundation Damage	26.3%	36.8%	21.1%	15.8%	100.0%
	percent within Location	3.9%	5.5%	4.6%	5.1%	4.7%
	percent of Total	1.2%	1.7%	1.0%	0.7%	4.7%
Nothing Happened	Count	120	112	82	56	370
	percent within Foundation Damage	32.4%	30.3%	22.2%	15.1%	100.0%
	percent within Location	93.0%	88.2%	94.3%	94.9%	92.0%
	percent of Total	29.9%	27.9%	20.4%	13.9%	92.0%
	Count	129	127	87	59	402
	percent within Foundation Damage	32.1%	31.6%	21.6%	14.7%	100.0%
	percent within Location	100.0%	100.0%	100.0%	100.0%	100.0%
	percent of Total	32.1%	31.6%	21.6%	14.7%	100.0%

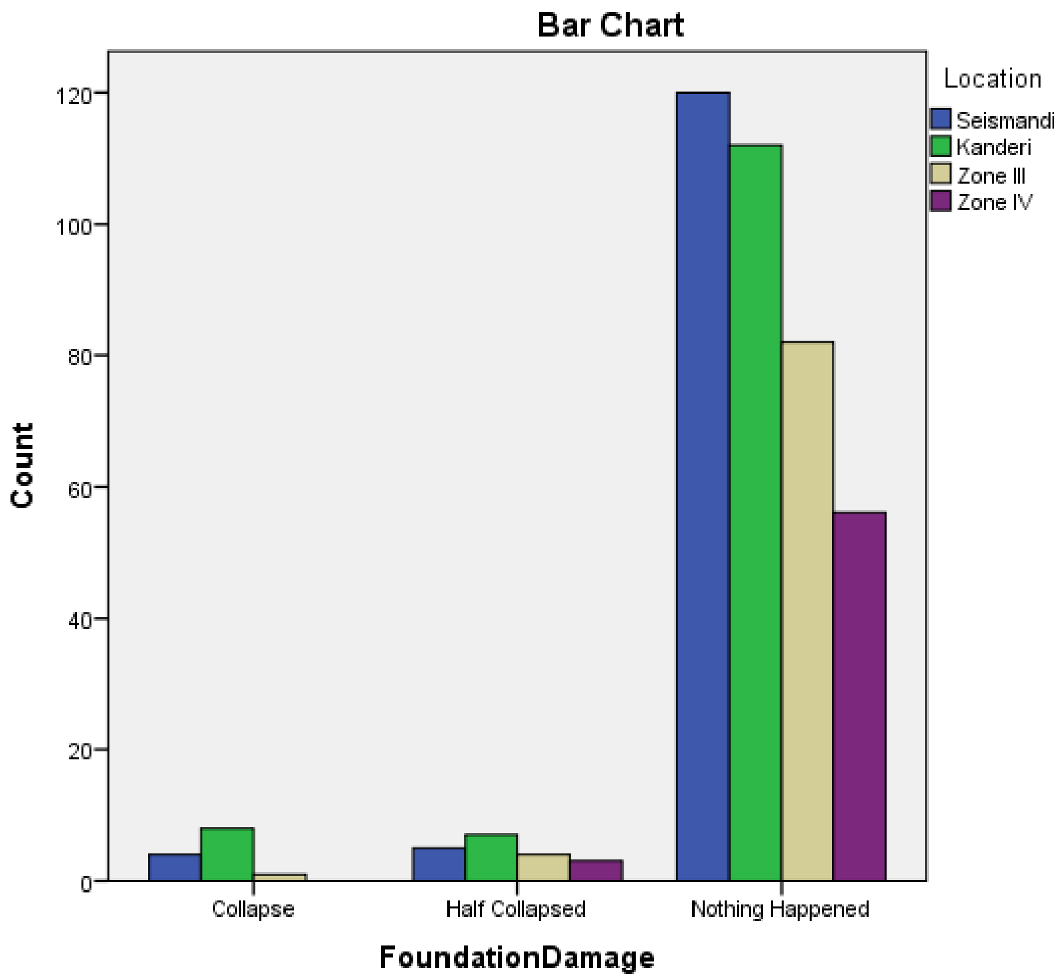

Figure 4.18: Foundation damage pattern in different zones, Source: Field work

4.5.18. Floor Damage

From table 4.12 and Figure 4.19 it was concluded that Kanderi was the worst affected as far as damage to the floor due to 2010 floods is concerned, followed by Siesmandi, than zone-III and followed by zone-IV. Similar patterns of damage were observed for collapsed and half collapsed foundation structure.

Table 4.12: Floor damage to surveyed buildings, Source: Field work

Floor Damage Pattern		Location				Total
		Seismandi	Kanderi	Zone III	Zone IV	
Half Collapsed	Count	13	14	6	4	37
	percent within Floor Damage	35.1%	37.8%	16.2%	10.8%	100.0%
	percent within Location	10.1%	11.0%	6.9%	6.8%	9.2%
	percent of Total	3.2%	3.5%	1.5%	1.0%	9.2%
Nothing Happened	Count	116	113	81	55	365
	percent within Floor Damage	31.8%	31.0%	22.2%	15.1%	100.0%
	percent within Location	89.9%	89.0%	93.1%	93.2%	90.8%
	percent of Total	28.9%	28.1%	20.1%	13.7%	90.8%
	Count	129	127	87	59	402
	percent within Floor Damage	32.1%	31.6%	21.6%	14.7%	100.0%
	percent within Location	100.0%	100.0%	100.0%	100.0%	100.0%
	percent of Total	32.1%	31.6%	21.6%	14.7%	100.0%

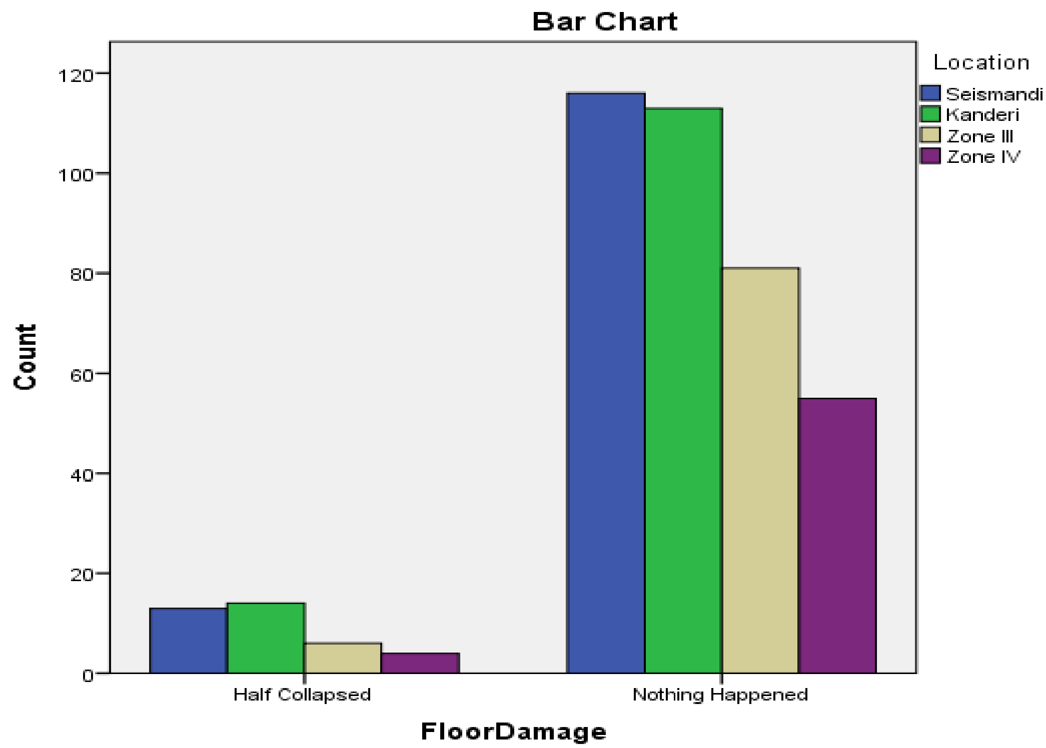

Figure 4.19: Floor damage pattern in different zones, Source: Field work

4.5.19. Wall Damage

From table 4.13 and Figure 4.20 it was concluded that Kanderi was the worst affected as far as damage to the walls (including being developed with cracks and half collapsed walls)of different buildings due to 2010 floods is concerned, followed by Siesmandi, than zone-III and followed by zone-IV. Similar patterns of damage were observed for collapsed and half collapsed foundation structure.

Table 4.13: Wall Damage in different zones, Source: field work

Walls Damage						
Wall Damage Pattern		**Location**				**Total**
		Seismandi	**Kanderi**	**Zone III**	**Zone IV**	
Developed Cracks	Count	31	36	14	4	85
	percent within Walls Damage	36.5	42.4	16.5	4.7	100.0
	percent within Location	24.0	28.3	16.1	6.8	21.1
	percent of Total	7.7	9.0	3.5	1.0	21.1
Half Collapsed	Count	12	13	6	3	34
	percent within Walls Damage	35.3	38.2	17.6	8.8	100.0
	percent within Location	9.3	10.2	6.9	5.1	8.5
	percent of Total	3.0	3.2	1.5	0.7	8.5
Nothing Happened	Count	86	78	67	52	283
	percent within Walls Damage	30.4	27.6	23.7	18.4	100.0
	percent within Location	66.7	61.4	77.0	88.1	70.4
	percent of Total	21.4	19.4	16.7	12.9	70.4
	Count	129	127	87	59	402
	percent within Walls Damage	32.1	31.6	21.6	14.7	100.0
	percent within Location	100.0	100.0	100.0	100.0	100.0
	percent of Total	32.1	31.6	21.6	14.7	100.0

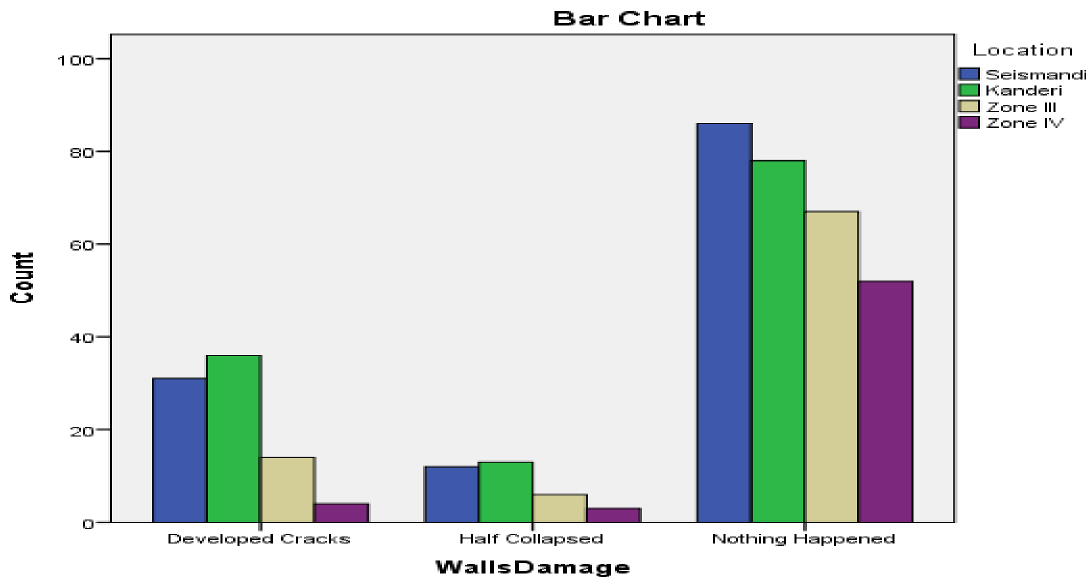

Figure 4.20: Wall Damage pattern in different zones, Source: field work

4.5.20. Roof damage to Buildings

From table 4.14 and Figure 4.21, it was concluded that Kanderi was the worst affected as far as damage to the roof of the buildings is concerned due to 2010 floods, followed by Siesmandi, than zone-III and followed by zone-IV. Similar patterns of damage were observed for half collapsed walls.

Table 4.14: Roof Damage pattern in different zones, Source: field work

Roof Damage						
Roof Damage Patterns		**Location**				**Total**
		Seismandi	**Kanderi**	**Zone III**	**Zone IV**	
Collapse	Count	4	7	3	2	16
	percent within Roofs Damage	25.0	43.8	18.8	12.5	100.0
	percent within Location	3.1	5.5	3.4	3.4	4.0
	percent of Total	1.0	1.7	0.7	0.5	4.0
Nothing Happened	Count	125	120	84	57	386
	percent within Roofs Damage	32.4	31.1	21.8	14.8	100.0
	percent within Location	96.9	94.5	96.6	96.6	96.0
	percent of Total	31.1	29.9	20.9	14.2	96.0
	Count	129	127	87	59	402
	percent within Roofs Damage	32.1	31.6	21.6	14.7	100.0
	percent within Location	100.0	100.0	100.0	100.0	100.0
	percent of Total	32.1	31.6	21.6	14.7	100.0

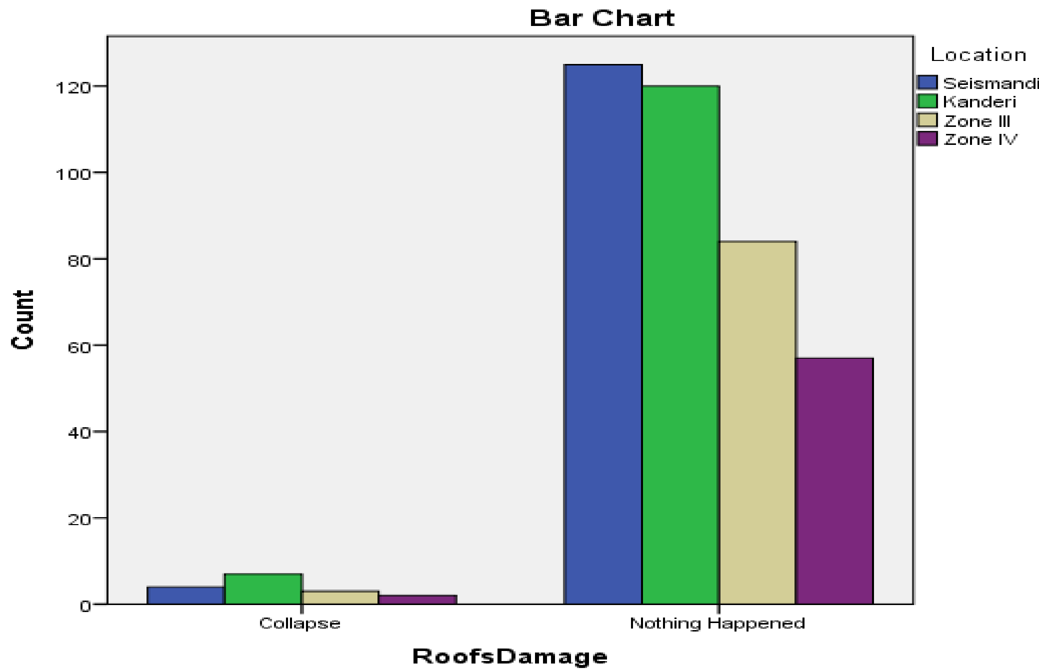

Figure 4.21: Roof damage pattern in different zones, Source: field work

4.5.21. Actual Construction Cost

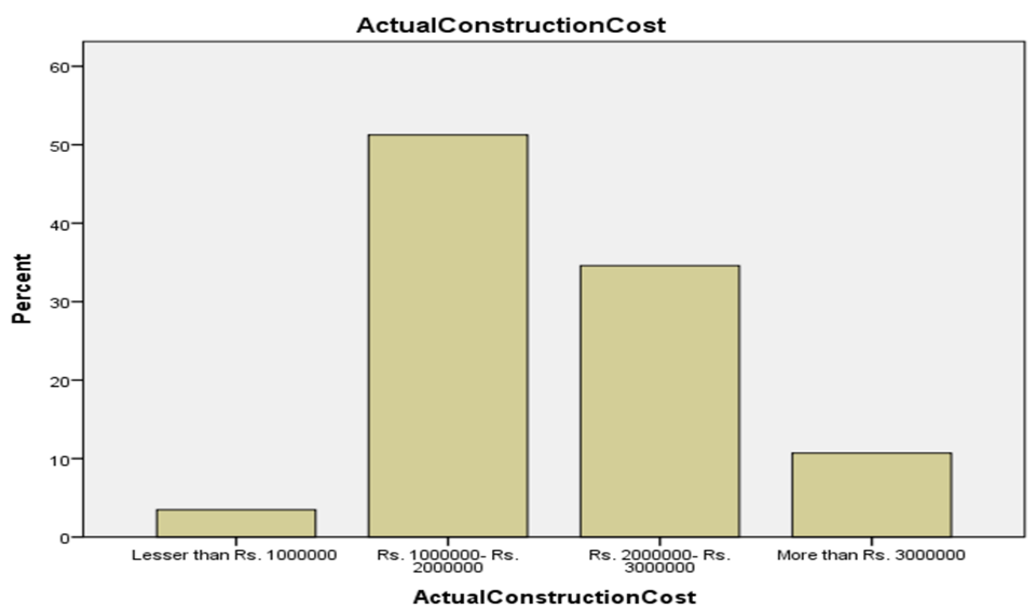

Figure 4.22: Actual construction cost, Source: field work

From Figure 4.22, it was concluded that the actual construction cost as confirmed by the residents for 51.2percent of the surveyed buildings ranged from Rs.1000000 to Rs.2000000. The construction cost for 34.6percent of the affected surveyed buildings ranged from Rs.2000000 to Rs.3000000 while the actual construction cost of 10.7 percent of the affected buildings ranged more than Rs.3000000 and for 3.5percent of the affected buildings, the actual construction cost ranged less than Rs.1000000.

4.5.22. Location and duration of flood

Figure 4.23 shows the relationship Between location and the duration of flood. From this Figure, it was concluded that 90percent surveyed buildings in 2010 floods which took place at Seismandi had duration of almost 48 hours while 23percent of the floods taking place in same area had duration of 72 hours and 16percent that flood had duration of 24 hours. 98percent of the floods which took place at Kanderi lasted for 48 hours while 18percent last for 72 hours and 16.6percent lasted for 24 hours in the same area. 50percent of the floods in the zone III had duration of 72 hours while 5percent floods had duration of 48 hours and 30percent of the floods had duration of more than 72 hours in the same area. However in zone IV, 42percent of the floods had duration of 72 hours while 6percent of the floods had duration of 48 hours and 5percent of the floods last more than 72 hours.

4.5.23. Material used in roofs

Table 4.15: Material used in roof in different zones, Source: field work

Locations / Roof Materials	Seismandi	Kanderi	Zone III	Zone IV	Total
Count	75	64	47	34	220
RCC percent of Total	18.7	15.9	11.7	8.5	54.7
Std. Residual	.5	-.7	-.1	.3	
Count	43	55	33	19	150
Wood+straw percent of Total	10.7	13.7	8.2	4.7	37.3
Std. Residual	-.7	1.1	.1	-.6	
Count	11	8	7	6	32
Brick tiles percent of Total	2.7	2.0	1.7	1.5	8.0
Std. Residual	.2	-.7	.0	.6	
Count	129	127	87	59	402
Total percent of Total	32.1	31.6	21.6	14.7	100.0

From table 4.11, it was concluded that the roofs of 18.7percent of the surveyed buildings located at Seismandi were made up of RCC while the roofs of 10.7percent of the buildings were made up of wood, straw and the roofs of 2.7percent of the buildings were made up of brick tiles. The roofs of 15.9percent of the buildings located at Kanderi were made up of RCC while the roofs of 13.7percent of the buildings were made up of wood, straw and the roofs of 2percent of the buildings were made up of brick tiles. The roofs of 11.7percent of the buildings located at Zone III were made up of RCC while the roofs of 8.2percent of the buildings were made up of wood, straw and the roofs of 1.7percent of the buildings were made up of brick tiles. The roofs of

8.5percent of the buildings located at Zone IV were made up of RCC while the roofs of 4.7percent of the buildings were made up of wood, straw and the roofs of 1.5percent of the buildings were made up of brick tiles.

4.5.24. Wall material and location

Table 4.16: Material used in walls in different zones, Source: field work

Wall materials \ Locations		Seismandi	Kanderi	Zone III	Zone IV	Total
Bricks	Count	86	70	50	37	243
	percent of Total	21.4	17.4	12.4	9.2	60.4
	Std. Residual	.9	-.8	-.4	.2	
Blocks	Count	3	4	5	7	19
	percent of Total	0.7	1.0	1.2	1.7	4.7
	Std. Residual	-1.3	-.8	.4	2.5	
Mud	Count	5	14	11	8	38
	percent of Total	1.2	3.5	2.7	2.0	9.5
	Std. Residual	-2.1	.6	1.0	1.0	
Stones	Count	2	6	7	4	19
	percent of Total	0.5	1.5	1.7	1.0	4.7
	Std. Residual	-1.7	.0	1.4	.7	
Adobe	Count	33	33	14	3	83
	percent of Total	8.2	8.2	3.5	0.7	20.6
	Std. Residual	1.2	1.3	-.9	-2.6	
Total	Count	129	127	87	59	402
	percent of Total	32.1	31.6	21.6	14.7	100.0

From table no: 19, it was concluded that the walls of 21.4 percent of the surveyed buildings located at Seismandi were made up of bricks while the walls of 0.7percent of the buildings were made up of blocks and the walls of 1.2percent of the buildings were made up of mud. Whereas, the walls of 0.5percent of the buildings were made up of stones and the walls of 8.2percent of the buildings were made up of adobe. The walls of 17.4percent of the buildings located at Kanderi were made up of bricks while the walls of 1percent of the buildings were made up of blocks and the walls of 3.5percent of the buildings were made up of mud. Whereas, the walls of 1.5percent of the buildings were made up of stones and the walls of 8.2percent of the buildings were made up of adobe. The walls of 12.4percent of the buildings located at Zone III were made up of bricks while the walls of 1.2percent of the buildings were made up of blocks and the walls of 2.7percent of the buildings were made up of mud. Whereas, the walls of 1.7percent of the buildings were made up of stones and the walls of 3.5percent of the buildings were made up of adobe. The walls of 9.2percent of the buildings located at Zone IV were made up of bricks while the walls of 1.7 percent of the buildings were made up of blocks and the walls of 2percent of the buildings were made up of mud. Whereas, the walls of 1percent of the buildings were made up of stones and the walls of 0.7percent of the buildings were made up of adobe.

4.5.25. Floor material and location

Table 4.17: Material used in floor in different zones, Source: field work

Locations Floor / Material		Seismandi	Kanderi	Zone III	Zone IV	Total
Soil	Count	20	25	15	15	75
	percent of Total	5.0	6.2	3.7	3.7	18.7
	Std. Residual	-.8	.3	-.3	1.2	
PCC, bricks, tiles	Count	109	102	72	44	327
	percent of Total	27.1	25.4	17.9	10.9	81.3
	Std. Residual	.4	-.1	.1	-.6	
Total	Count	129	127	87	59	402
	percent of Total	32.1	31.6	21.6	14.7	100.0

From table no: 34, it was concluded that the floors of 5percent of the total surveyed buildings located at Seismandi were made up of soil while the floors of 27.1percent of the buildings were made up of PCC, bricks and tiles. The floors of 6.2percent of the buildings located at Kanderi were made up of soil while the floors of 25.4percent of the buildings were made up of PCC, bricks and tiles. The floors of 3.7percent of the buildings located at Zone III were made up of soil while the floors of 17.9percent of the buildings were made up of PCC, bricks and tiles. The floors of 18.7percent of the buildings located at Zone IV were made up of soil while the floors of 81.3percent of the buildings were made up of PCC, bricks and tiles.

Chapter5

CONCLUSIONS & RECOMMENDATIONS

This chapter includes Discussions and Conclusions in which key findings are discussed to debate on hypotheses acceptance or rejection. Furthermore, conclusion, limitations and future research indications are also in this chapter.

5.1. Discussion

The global environmental changes lead towards an increasing number of floods. The increasing rate in floods for the past few years, is considered more damaging and dangerous. However all the countries of the world are at same risk due to floods, but the countries which are rich in agriculture are considered more at risk due to these. The studies done in the past regarding the damaging effects of floods did not include the study of the building materials. This study however provides the required information about the construction materials used in the construction of buildings which were affected by the floods. This led to the better understanding that which construction materials were better to be used for preventing the damages caused by the floods. For this study, the data was collected from a district of KPK known as Nowshera which was greatly affected by the 2010 floods. For this study, Dr Naveed's model was considered. The research was divided into three main sections i.e pre-field research, Field research and post-field. Selected areas of Seismandi & Kanderi (10.4 KM) were further divided into 4 sub sections according to frequency of floods and elevation from MSL. Different results were obtained from the collected data. The results obtained from the data collected showed that Seismandi was the most affected area than Kanderi, Zone III and Zone IV. It was observed that the buildings which were mostly affected by the floods were built in the years from 1998 to 2010. Most of the affected buildings belonged to the owners themselves. It was observed that the floods damaged more of the residential areas. The buildings with a foundation depth of 3 ft were more affected by the floods. Different building materials used in the construction of the affected buildings, were also recorded. These materials included the construction material used in the construction of roofs, foundations, walls and floors. From the collected data, it was concluded that the buildings which had bricks as their foundation material and wall material located at Kanderi and Seismandi, were greatly affected by the floods while the buildings having RCC as their roof material located at Seismandi were greatly affected by the floods. The buildings with single storey were greatly affected by the floods as they were easily targeted by the overflow of the water. It was observed that the buildings which included cement mortar during their constructions were damaged by the floods more easily. The buildings with regular openings at window levels were more affected by the floods. The most common type of flood observed was medium with a max water level of 5 to 10 ft. Most of these floods last for 48 hours. The foundations and floors of the damaged buildings were largely collapsed while the walls of such buildings developed cracks. However the roofs of the largely affected buildings remained safe. To repair these damages, different costs were required. The most common wall repair cost ranges from Rs. 25000 to Rs. 40000 while the most common roof repair cost ranges from Rs.

20000 to Rs. 40000. The floor repair cost ranges from Rs. 10000 to Rs. 35000 and the actual cost of the damages ranges from Rs. 1000000 to Rs. 2000000. These results helped in concluding the collected data that led towards a better research study. From this study, it was concluded that the physical vulnerability to the floods also depend on the type of structure. Five types of structures are there and it was observed that the structure type I and II were less vulnerable to floods while structure type IV and V were more vulnerable to floods. The explanation of these structures is given below.

- **Structure type I: Reinforced Concrete Frame**

  Reinforced concrete frames were found as commercial units mostly. These varied from 3-4 storied buildings, however majority of such types of buildings were 2- 3 storied. These buildings have strong resistance against floods in general (Figure 4.1). Due to high cost of construction, RCF were not very commonly used in the areas of research. Mostly commercial buildings are constructed in RCF type.

- **Structure type II: Reinforced Concrete Frame with infill masonry**

  Reinforced concrete with masonry infill or RCI exists in large numbers in urban areas. These buildings may consist of 3 to 4 stories but in study area mostly these were 2 storied. Mostly buildings are non-engineered and relatively vulnerable compared to the RCF type due to poor quality of construction and materials use (Figure 4.2). The flood performance of the RCI buildings is normally below the standards.

- **Structure type III: Un-Reinforced Brick Masonry- Cement Mortar**

  These types of buildings also called UBM-CM, are more common in study area for residential usage. Brick Masonry with cement and sand mortar is used for these type of buildings. Such type of buildings are maximum up to 3 stories with RCC roofing. These building are more vulnerable to flood damages (Figure 4.3).

- **Structure type IV: Un-Reinforced Brick Masonry- Mud Mortar**

  These building types also called UBM-MM are more common in study region for residential usages. Brick Masonry with Mud mortar is used for this type of buildings. Such types of buildings are single storied with timber and girder roofing (Figure 4.4). This type of buildings also are more vulnerable to floods and its associated damages

- **Structure type V:Adobe Structures or Mud Wall Structures**

  These are low cost buildings incorporating local material and expertise. Such type of buildings predominantly exist in rural areas or may be nonresidential Deras in outskirts of towns, while as scarcely in urban areas as well. Construction comprises of mud walls i.e. mud bricks with mud mortar for binding and Timber roofing, or girder roofing (Figure 4.5). The nature of major damages to adobe houses in Pakistan during 2010 floods has been pronounced.

5.2. Conclusions

This research is conducted in isolation keeping similar type of methodology for qualitative earthquake risk and vulnerability assessment where building inventory is created in similar way. Same method is used for Risk assessment of Punjab province by PDMA Punjab in consultation with NDMA funded by WB.

Main conclusions of the study are suggested as follows:-

- Accuracy of the visual inspection was about 78 percent endorsed from field surveys.
- Reinforce concrete framed structures were most resilient against floods while adobe structures were the fragile most. Concrete with infill masonry, unbound brick masonry with Cement mortar and same with mud mortar were the 2^{nd}, 3^{rd} and 4^{th} most efficient/resilient buildings against floods respectively.

5.3. Recommendations for Future Work

- Detailed Building Inventory need to be developed using more sophisticated methods and may be compared with this study.

- Although accuracy of the visual inspections has been tested previously using projected censes record of 1998, same is required to be verified through latest censes 2017 record.

- Flood vulnerability assessment with 100m x 100 m grid mesh size is used for the 1^{st} time. Similar (reduced) scaled building inventory and risk/vulnerability assessment is needed to be done in collaboration with PDMA KPK for better accuracy at least for flood prone areas, if not for the entire province.

- The study is needed to be shared with PDMA KPK for appropriate measures to be taken in flood management planning and resource allocation as per the vulnerability scales.

For future research study, following indications are given:

- This research study can be used for future studies regarding damages caused by floods and earthquakes in different areas of the world.
- The study should be considered by the people who are looking to buy houses in safe areas. They should follow the given instructions to build a safe house for protecting it against the floods.
- More research studies regarding the types of structures should be conducted in order to determine the safest materials used for constructing a building to prevent it from hazardous effects of the floods

5.4. Limitations

There are many limitations in this research study. The sample size selected for this study was very small and few areas were selected to collect the data. However, the selected areas were mostly affected by the 2010 floods. The study was limited to few areas as the entire province of KPK could not be taken under consideration. As the data was collected for the floods that took place in 2010, the information obtained was not considered completely authentic. The researcher faced problems during collecting of data and assessing the same as it was a tough job to do. For this purpose, the working of different softwares were also learnt by the researcher. Some other limitations of work were as follows:

- Although building structure layout, its height, construction detailing and quality of material affect the response of the building to a hazard like flood that varying for different buildings. However, for vulnerability assessment the buildings are classified in five major groups for scoring, which are idealized as per the experience of building construction and reconstruction in the localities but that is nevertheless a reasonable approximation considering the district, tehsil and UC levels for assessment.
- Vulnerability curve used in present study was used by Engr. Dr. Naveed Ahmad for working in an NDMA project for Charsadda city and surroundings. Analyzing the fragility functions, vulnerability scoring for each building typology was obtained corresponding to the damageability of building and was directly used in this study. The vulnerability scores derived herein refers to the damage parameter i.e water depth for flood hazard that has 50 percent chance to cause damage to the building. The vulnerability scoring is a qualitative index which for a given hazard, can be used to quantify the relative vulnerability of building typologies in a given area and to develop the vulnerable map for that area. The derived maps from vulnerability scoring are used to understand the spatial pattern of vulnerabilities in the area.
- The building vulnerability curves used in the present study are adopted and supported by the experimental and numerical (computer softwares based)

investigation on the building materials and model structures. However, fragility functions and vulnerability curves for other infrastructures (water/waste water system, roads, railways, electric power, etc.) are based on the earthquake observations, which are obtained from worldwide online database due to the unavailability of observation-based data in Pakistan. However efforts are made to carefully select fragility functions (material, geometry and detailing dependent) that can reasonably represent the performance of our infrastructure.

- The primary data for physical infrastructures used in the present study Kanderi area is obtained through field survey for a 402 sample units. This was used to verify secondary data of standard template cell technique used to develop the vulnerability map. The data used by this technique have been up to maximum 82percent correct previously for relatively large scale projects. So it can't be taken as 100percent correct as it is validated through field observations.

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Annexure - A

Physical Vulnerability Study to Floods - Seismandi Area

(Household level Questionnaire)

Questionnaire No

Purpose of Questionnaire: To ask survey questions relating flood situation & its impacts on buildings inside study area. The information shall be used for academic purpose of my MS thesis.

1. General Information

Date: ________________________ Name of Respondent:______________________

Location: _________________ Building co-ordinates______________________

Construction of Building ✓

Between 2010-2017 Between 1998- 2010 Between 1985-1998 Before 1985	

Ownership: ✓

Own Rent	

2. Elements at Risk ✓

Utility	Commercial	Residential	Education	Mosque	Health	Others
Foundation depth	1 ft	2 ft	3 ft	> 3 ft		
Fdn material	Bricks	Stones	other			
Type of Structure	Bearing Walls	Coulmns	Brick masonry	Framed		
Wall Material	Bricks Adobe	Blocks	Mud	Stone		
Roof Material	RCC	Wood+ Straw	Brick tiles			
Floor Material	Soil	PCC, Bricks, Tiles				
No. of storey	1	2	3	>3		
Binder	Clay	Cement Mortar	Other			
Openings	Large Regular/normal Location					

3. Flood occurrences ✓

Type of flood	Low	Medium	high	
Duration of flood water	24 hrs	48 hrs	72hrs	>72 hrs
Maximum water level	0 – 5 ft	5-10 ft	10-15 ft	>15 ft

4. Flood History:

Date	Water level (ft)	Duration (days)

5. Elements of Building structure failure

Element	Damage
Foundation	
Floor	
Wall	
Roof	

Note: C = Collapse, DC= developed cracks, HC= Half Collapsed, NH= Nothing Happened

6. Repair Cost

Element	Repair Cost (Rs)	Actual Construction Cost
Floor		
Wall		
Roof		