International Research Journal of MMC (IRJMMC)
ISSN 2717-4999 (Online) | 2717-4980 (Print)
Volume 6, Issue 3 | August 2025 | Special Issue

Integrated Approaches for Making Settlements Resilient from Earthquake Vulnerability: A Case Study of Urban and Rural Setting in Jajarkot, Karnali Province, Nepal

Ramesh Prasad Singh, PhD[1] | B. M. Praveen[2]

[1]Post-Doctoral Fellow, Institute of Engineering and Technology,
Srinivas University, Mangaluru, India

[2]Professor, Institute of Engineering and Technology
Srinivas University, Mangaluru, India

Corresponding Author
Ramesh Prasad Singh
Email: rameshntnu@gmail.com

To Cite this article: Singh, R. P., & Praveen, B. M. (2025). Integrated approaches for making settlements resilient from earthquake vulnerability: A case study of urban and rural setting in Jajarkot, Karnali Province, Nepal. *International Research Journal of MMC, 6*(3), 6–25. https://doi.org/10.3126/irjmmc.v6i3.82822

Submitted: 15 April 2025 **Accepted:** 5 May 2025 **Published:** 7 August 2025

Abstract

This paper explores the integration of indigenous and engineering approaches to reduce earthquake vulnerability in both urban and rural settings of Jajarkot District, Nepal—specifically focusing on Bheri Municipality (Khalanga Bazar) and Barekot Rural Municipality, the latter being the epicenter of the 6.4 magnitude earthquake on November 3, 2023. The earthquake caused significant damage in Jajarkot and Rukum districts, underscoring the urgency of risk reduction. The study highlights that ongoing changes, such as modernization and population growth, have increased the vulnerability of settlements. Four key issues contributing to this vulnerability include poor living environments, weak governance, increasing social segregation, and the erosion of traditional materials and knowledge. The research emphasizes that both urban and rural areas require tailored mitigation strategies that blend technical solutions with local knowledge. Engineering and non-engineering studies underline the complexity of addressing both existing and future built environments. In both settings, communities possess valuable skills, traditional construction knowledge, and mutual support systems that, if harnessed effectively, can enhance resilience. The study concludes that relying solely on either engineering or indigenous methods is insufficient in the face of rapid urbanization and limited local resources. A hybrid approach that leverages traditional building

forms, local materials, and collective practices alongside modern engineering techniques is essential for effective and sustainable earthquake risk mitigation.

Keywords: earthquake vulnerability, engineering knowledge, indigenous knowledge, resilient reconstruction, rural setting, territorial perspective, traditional building characteristic, urban setting

1. Introduction

The historical development of earthquakes in Nepal shows that the country has experienced many devastating earthquakes in the past. The deadliest earthquake occurred in 1934 A.D. The magnitude of 8.34 R-scale killed 8519 people, collapsed 80,893 buildings, and severely damaged more than 1,26,355 houses (JICA, 2002). After that, the earthquake of 1988 A.D. of magnitude 6.6 R-scale mainly affected the eastern development region and some parts of the central development region of Nepal. It caused 721 deaths, 6553 injuries, and damage to more than 64174 houses (Dixit, 2003). Similarly, the earthquake with its epicenter near the border of Nepal and the Indian state of Sikkim in 2011 of magnitude 6.9 R-scale killed at least 111 people, 6000 buildings were completely collapsed, and 20000 buildings were partially collapsed. In addition to the above, several earthquakes of small to medium-sized magnitude R-scale were also observed between 1934 and 2011. Around 11,000 people have lost their lives in major earthquakes in Nepal in this century (ibid).

The earthquakes of similar size magnitude of 1934 A.D. that occurred in the 19th Century are: 1810, 1833, and 1866 (KVERMP, 2005). The seismic records of the region suggest that an earthquake of a greater magnitude occurs approximately every 75-80 years, indicating that a devastating earthquake is inevitable in the long term and likely to take place soon. On 25th April 2015, a 7.6 –R scale earthquake as recorded by Nepal's National Seismological Centre (NSC), struck Barpak of Gorkha, Nepal had not faced a natural shock of comparable magnitude for over 80 years. The catastrophic earthquake was followed by more than 300 aftershocks greater than magnitude 4.0 (as of 7 June 2015). Four aftershocks were greater than magnitude 6.0, including one measuring 6.8, which struck 17 days after the first big one with the epicenter near Mount Everest (NPC, 2016).

On November 3, 2023, a magnitude 6.4 R-scale earthquake struck near Jajarkot and Rukum West districts, resulting in numerous casualties and displacement. The epicenter was estimated to be in Ramidanda, in Jajarkot District. More than 150 people were killed in this earthquake. About 62,039 houses were affected across thirteen districts of Nepal, of which 26,550 collapsed (UNRCO Nepal, 2023).

The quake is the deadliest since 2015, when about 9,000 people were killed in two earthquakes in the Himalayan country. Whole towns, centuries-old temples, and other historic sites were reduced to rubble, then, with more than a million houses were destroyed at a cost to the economy of more than $6 billion (DP Net Nepal, 2023).

Several Engineering as well as non-engineering studies have also been undertaken for the mitigation of earthquake vulnerability. This is a very complex issue consisting of what to do about the existing and future built environments. Nepal's morphology reflects its diverse ecology, with significant differences between rural and urban settings across its mountainous, hilly, and Terai (plains) regions. Rural and urban settings are also defined by built forms of different types and linked together by a network of streets. People have enormous knowledge, skills, and resources in both settings that only need to be explored. Indigenous knowledge for earthquake mitigation and preparedness is not only manifested in buildings and structures but also in the morphological form of the spatial structure and house design on a territorial basis.

Figure 2: *Collapse of buildings at Kalanga Bazar (Bheri Municipality,Khalanga)*

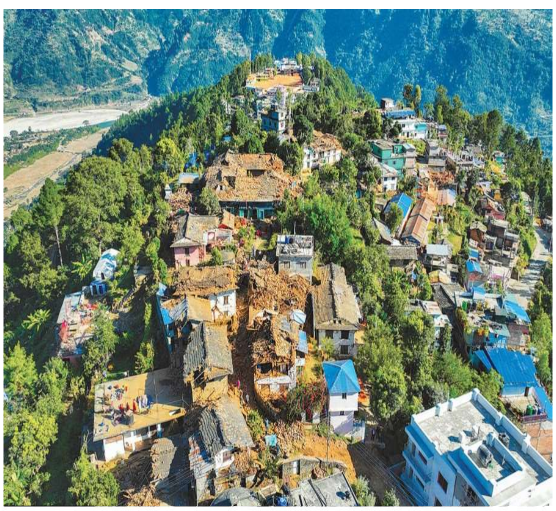

Figure 1*: Destruction due to earthquake (overall view of Bheri Municipality) & Jajarkot Durbar*

On the other hand, some research shows that the indigenous knowledge and capacity within the traditional community within the fixed territory are limited, which are not enough to contribute to earthquake resistance. Local knowledge often appears to be insufficient in the case of very infrequent disasters. The study has also added that only one approach may not work for earthquake safety as seismic safety of buildings has to be improved by better use of material and improved technology, as well as skill on one front, and by legal enforcement and awareness raising in the other.

The earthquake that struck Jajarkot, Nepal, highlighted the urgent need for disaster preparedness and risk reduction measures. The majority of the losses were attributed to weak infrastructure, particularly old and traditional houses made of stone and mud, which were unable to withstand the seismic activity. The earthquake also raised concerns about the poor construction of houses in the affected areas and the potential for more devastating earthquakes in the region.

Therefore, this article intends to explore the appropriate approach to protect both the life of the people and setting of the place from the earthquake hazard, in urban and rural setting of Jajarkot District (I.e. most vulnerable communities) in mid-western regions of for the reduction of earthquake disaster for a Least Developed Country (LDC) like Nepal with a limited resource base.

2. Theoretical perspectives on disaster vulnerability analysis

The analysis of Disaster vulnerability is dynamic and complex. Therefore, vulnerability assessment needs analytical judgment. The assessments focus on the factors that cause the severity of the loss and damage and on how capacity should be developed to reduce vulnerability in the future. Various indicators are considered for analyzing the disaster vulnerability depending upon the types of approaches followed (Singh,2016). Broadly, two types of perspectives are used to analyze disaster vulnerabilities.

2.1 Engineering perspectives

From an engineering perspective, disasters are linked to natural forces, and the approach itself is directed towards managing the risk to the physical as well as built environment (e.g., retrofitting buildings and structures, lifelines engineering, land use planning) (Bank off, 2000, cited in Jigyasu, 2002). In this perspective, historical record (time, place, extent, magnitude& intensity) of earthquake hazard, geology, site condition, age of structures, location of fault and its length & depth, and construction materials used are mainly required to analyze the disaster vulnerability (Singh,2016). Existing building stock in the city core is classified on the basis of its structural characteristics and location. Different models are used to calculate disaster risk (JICA, 2002).

However, these models lack people's linkage at the societal level as well as the social capital. This perspective tends to consider human beings as one of many elements at risk defined as population, buildings and civil engineering works, economic activities, public services, and infrastructures, etc., exposed to hazards. However, there is no reference to people, their community, and social associations, networks that underpin and facilitate life in our society. This approach suggests an emphasis on the hazard agent rather than the consequences of interactions between the hazard agent and the community, property, and the environment. This approach is mostly based on the top-down approach in development planning and disaster management, which fails to address local needs, ignores the potential of indigenous resources and capacities, and may have even increased people's vulnerabilities (Yodamani, 2001, cited in Jigyasu, 2002).

The dominant official thinking on mitigation in many countries is still very much based on scientific knowledge, with an emphasis on the technical over the socio-economic. One of the cornerstones of this thinking is that adequate building and planning codes and regulations can stop disasters from happening (Schilderman, 2004). Most of these codes prescribe buildings using concrete or steel frames, brick masonry, etc., that will withstand most earthquakes. There is a loss of confidence in traditional construction technologies.

The solutions they prescribe are more expensive and therefore out of reach of the poor. The main problem with these codes is that authorities cannot often enforce them, or sometimes ‘look the other way’. According to Ruskulis (2002), cited in Schilderman (2004), there is also a problem in that many codes do require a high specialist level of knowledge on the part of architects, contractors, and building control officers, which not all have, resulting in compromises being made on questions of safety. The amount of damage to buildings caused by an earthquake depends upon the amount of acceleration, velocity, and displacement experienced at a particular site created by the earthquake and the strength of the buildings to resist these forces (Ambrose &Vergun, 1999, cited in Bhatta, 1999). There are various factors in a building itself, like method of construction and material type used, building configuration in plan and also in elevation, age, number of stories, size of the building, etc., which are responsible for causing the damage to the building (ibid).

2.2 Social Perspective

The social perspective is based on recognition that hazards have an impact on people that is not dependent on the effect of the natural and built environment, which directly facilitates individual and collective changes in behavior of the people (e.g., encouraging support and/or adoption of protective measures) and increasing their capacity to adapt the adverse situations. In contrast to the engineering approach, in which relatively objective analyses of known data regarding the likelihood of hazard occurrence and its consequences inform the process, the latter occurs in a context defined by considerable social, political, economic, and psychological diversity (Kuban & Carey, 2001).

In the context of a social perspective, Hazard consequences cannot be understood in terms of the direct effects of the actions of the hazard. Rather, they reflect the interaction between hazard characteristics and those individual and community elements that increase susceptibility to experiencing loss from exposure to a hazard (i.e., increase vulnerability) and those that facilitate a capacity to adapt or adjust (i.e., increase resilience). In this context, risk management can be described in terms of the choices made regarding the reduction of vulnerability and the development of resilience or adaptive capacity.

Hasan (2005) suggests that the architects and engineers of Pakistan should learn from the Pakistan earthquake about the seismic resistance of local materials during the further design of seismic structures. During the Pakistan earthquake in 2005, many concrete houses collapsed, but mud houses survived. There are timber columns, beams, and roofs that are standing while the rubble walls around them have collapsed. He further suggests it is to popularize earthquake-resistant technology using local materials. This technology is well known. It is simple and economical. It has been extensively used in Yemen, Iran, and in Maharashtra in India. The simplified manuals for reducing the earthquake should be prepared at the community level to understand what to do and not to do.

Blaikie et al. (1994) recognize that vulnerability to hazards and risk not only affects one’s ability to cope with a disaster, but also affects a person’s means for mitigation (pre-disaster event) and recovery (post-disaster event). If social vulnerability creates hazard and risk emanation, then mitigation measures and improved recovery efforts aimed at vulnerability should help minimize loss.

Due to the existence of the political paradox, mitigation can imply a present problem in the hazard control system, with some social groups more susceptible than others to particular risks from hazards. Such efforts in hazard mitigation can uncover sensitive social issues, placing power elites and other influential stakeholders in difficult political circumstances.

Blaikieet, et. Al., (1994) employ their study of risk and vulnerability around the formula: Risk (Disaster) = Hazard + Vulnerability. This formula represents the author's view that disaster risk is directly affected by the hazard produced and the degree of hazard vulnerability experienced by exposed persons in a particular period and space.

2.3 Integrating approach (combination of engineering and social perspective)

Only one perspective, i.e., either social or engineering, can have the capacity to analyze earthquake vulnerability. For the reduction of earthquake risk, an integrated approach consisting of engineering (i.e, also called scientific approach) and social approaches (i.e., also called indigenous approach) is crucial. Integrated risk assessment models for vulnerability analysis of the system interdependencies are necessary (Mercer et al. 2009).

In the social perspective, earthquake vulnerability cannot be quantified, but rather to develop measures of relative vulnerability to assess the behavior of different sub-systems expected to be impacted by the earthquake. These measures need to be considered along with the quantitative measures for the engineering components of the system. Integrating the two components, earthquake mitigation measures can only be made through assigning different importance factors to them. In this perspective, community is engaged through a collaborative effort with the stakeholders to identify the intrinsic and extrinsic components contributing to hazard vulnerability.

From an engineering perspective, major focus is given on developing structural systems that are seismic resistant, but it is not sufficient to address the overall seismic risk. However, this system has significantly less attention on networks of lifeline systems, economic systems, and social systems. One of the critical issues is to determine the overall vulnerability of the entire system subjected to a major seismic hazard event.

In the Integrated Perspective, it combines both approaches, i.e., indigenous and scientific approaches, which address the intrinsic components of hazards that depend on the effective level of each strategy /perspective (Singh, 2016). This integrating approach is an important tool to analyze the physical vulnerability in the settlement. The integrating approach is currently applied, which is called the contemporary approach, to reduce the earthquake risk in both urban and rural contexts of the Jajarkot earthquake.

3. Methodology

Research methodology is not only the description of tools for data collection, but it is a detailed plan and process of data collection methods, linking it to the relevant theories. Research methodology is thus a coherent set of rules and procedures, which can be used to investigate a phenomenon or situation (Singh, 2016). Methodology refers to more than a simple set of methods; rather, it refers to the rationale and the philosophical assumptions that underlie a particular study.

In this research, a combination of methodologies, including interviews, observation, consultation, and key informants' interviews, was conducted. Indigenous knowledge and skills, as well as engineering technological adaptation for building construction, are assessed from a professional point of view through institutional settings and from the people that is concerned with the place of study. People living in the local area and working in the professional institutions were covered for the collection of relevant information. indirectly interlinked with the earthquake-responsive activities and rural setting. Therefore, there are two sets of informants from the Urban and Rural settings of Jajarkot district.

The study has adopted a concurrent mixed-method; both quantitative and qualitative. The study has explored the appropriate approach to reduce the earthquake risk. In addition, Rapid Visual Assessment was carried out to assess the vulnerability of the existing building condition at both sites. For this, the buildings were divided into the following primary categories: (1) masonry buildings, (2) RCC buildings, (3) steel buildings, and (4) timber buildings. These can be further divided into various sub-categories. Based on their seismic resistance, the following vulnerability classification has been proposed based on the European Macro-seismic Scale (EMS-98) and modified during the development of the World Housing Encyclopedia.

Similarly, the damage to the buildings was classified as negligible to slight damage, moderate damage, substantial to heavy damage, very heavy damage, and destruction. Assessed buildings were further re-classified into three main categories such as most vulnerable, less vulnerable, and good condition. Based on this information vulnerable map and a violation map were prepared. The following methods were applied for building a Damage assessment;

Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)

- Hairline cracks in very few walls.
- Fall of small pieces of plaster only.
- Fall of loose stones from the upper parts of buildings in very few cases.

Grade 2: Moderate damage (slight structural damage, moderate non-structural damage)

- Cracks in many walls.
- Fall of fairly large pieces of plaster.
- Partial collapse of chimneys.

Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)

- Extensive cracks in most walls.
- Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).

Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)

- Serious failure of walls; partial structural failure of roofs and floors.

Grade 5: Destruction (very heavy structural damage)

- Total or near total collapse.

3.1 Study Area

The Western cluster of Nepal (Western, Mid-western, and Far-western regions) has not experienced a major earthquake for over 500 years. The energy released by the 6.4 Richter scale earthquake in Ramidanda of Jajarkot on November 3, 2023, was minuscule compared to the massive energy stored beneath the Western cluster of Nepal." Below is the location of Jajarkot district on the map of Nepal. Bheri Municipality (i.e. Khalanga Bazar) of Jajarkot District, one of my case study areas, lies in the urban setting, while my second study area is Barekot Rural Municipality, which lies in a rural setting. The epicenter of the Jajarkot earthquake on 3rd November, 2023, of magnitude 6.4 R-scale was in Ramidada of Barekot rural municipality.

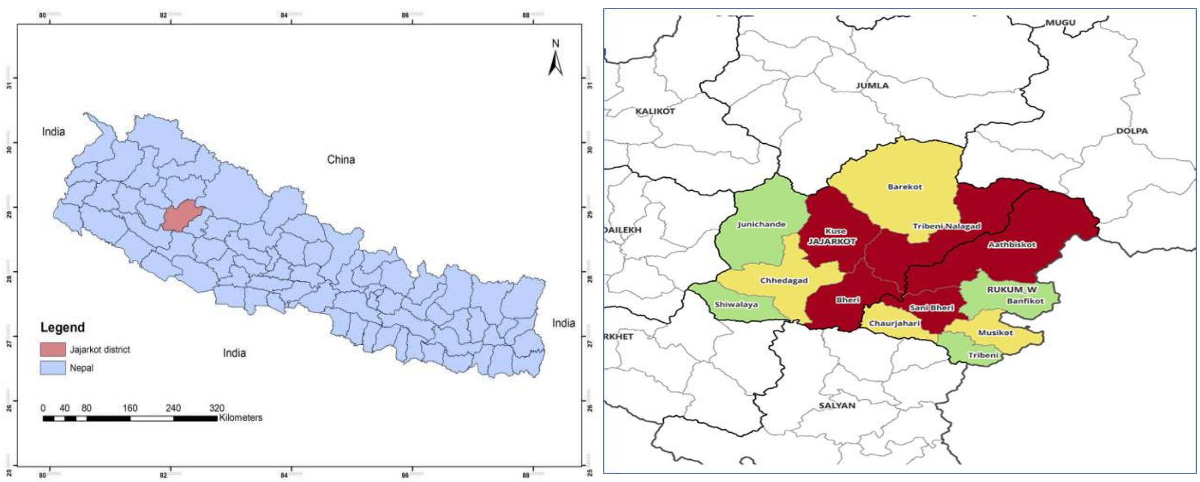

Figure 3: *Jajarkot District in the map of Nepal* *Most affected areas in Jajarkot Earthquake*

3.2 Earthquake Situation Analysis

On 3rd November,2023, the earthquake of magnitude 6.4 R-scale occurred with epicenter in Ramidada of Barekot rural municipality, Jajarkot. Due to the occurrence of this earthquake, there was significant loss of life and property in Jajarko and Rukum districts, while the tremors were felt as far away as Kathmandu. This has had a devastating effect on the lives and livelihoods of the people in one of the most impoverished areas of Nepal. The Jajarkot quake is the deadliest since 2015 when about 9,000 people were killed in two earthquakes in Nepal. The impacts of the earthquake reverberated through essential sectors such as health and education, with infrastructure damages, both complete and partial, worsening the challenges faced by the community (Bheri Municipality, 2024).

A total of more than 150 persons were killed in Jajarkot and Rurkum West District out of 13 affected districts and 35,321 households (about 175,000 persons) had their houses damaged. (ibid)

In case of Damage of houses and infrastructure, about 35,321 houses have been damaged in 13 districts as a result of the earthquake. Among these, about17,792 houses have been completely damaged, while about 17,529 have been partially damaged which are not suitable for inhabitation. (ibid)The houses in this area are mostly weak structures made with mud and stone walls, and this can be attributed to the large-scale damage. For example, in the earthquake affected municipalities of Jajarkot and Rukum West, as many as 90 to 97% of the houses had their walls made with mud-bonded stone or bricks, as per 2021 census data from the National Statistics Office. A total of 213 schools have been impacted by the earthquake, out of which 91 were completely damaged while 122 were partially damaged (DPNET report 3, Nov 6). Some Government offices have also been damaged. This disruption extends beyond classrooms, affecting essential facilities such as toilets, labs, libraries, and electrical/solar infrastructure.

Impact on the livelihoods was also observed in this earthquake hazard. Agriculture is the main livelihood of the populations in these areas, followed by remittances. Households have faced challenges in the harvesting of paddy and then sowing of wheat crop, especially those whose houses have been damaged and may have lost livestock and farming tools. The consequential loss of property, agricultural farms, and livestock has plunged many into financial crises, with daily survival becoming a difficult challenge.


Damage to the buildings and vulnerable observation tour in the study area for exploring the existing and mitigation approaches to reduce the earthquake disaster in Khalanga, Bheri Municipality.

The buildings made up of stone in mud mortar are found mostly damaged/collapsed during the earthquake of 2023. When we look at the construction-wise damage of the buildings, mostly residential buildings have collapsed.

The majority of the buildings were found collapsed because of two main reasons;

- Buildings planned, conceived, and constructed by owners without any input from engineers, not designed by an engineer, can have critical structural weaknesses leading to collapse; (which applies to most collapsed buildings in the recent earthquake)

Buildings designed by an engineer but constructed differently; for example, it is not uncommon in Nepal to add extra floors on top of a building that has been designed as a 2-3-story building. Similarly, the quality of materials (concrete and reinforcing steel) has been found deficient in many buildings.

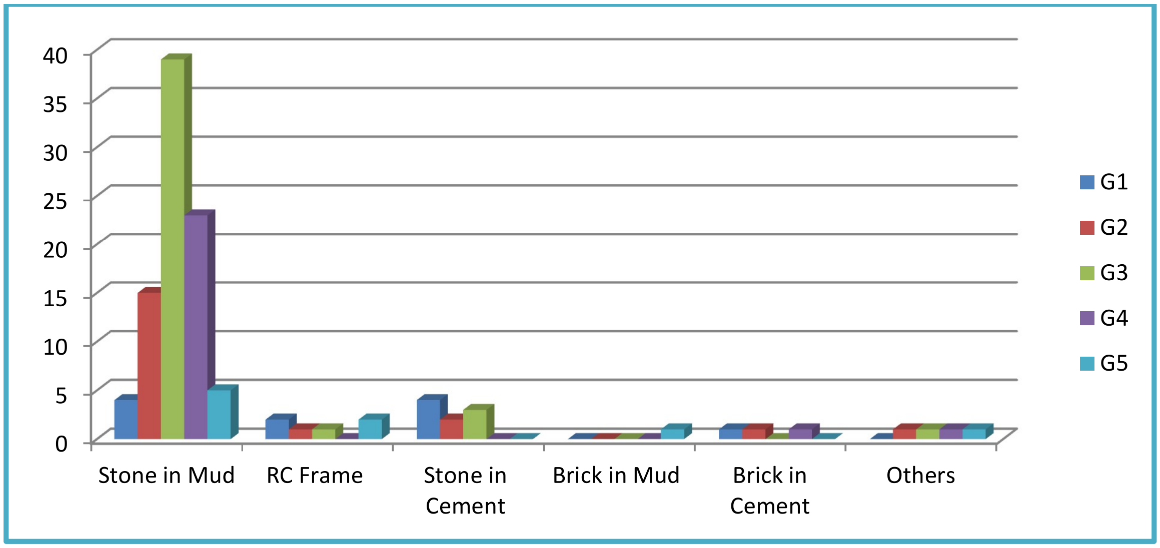

Figure 4: *Construction wise buildings*

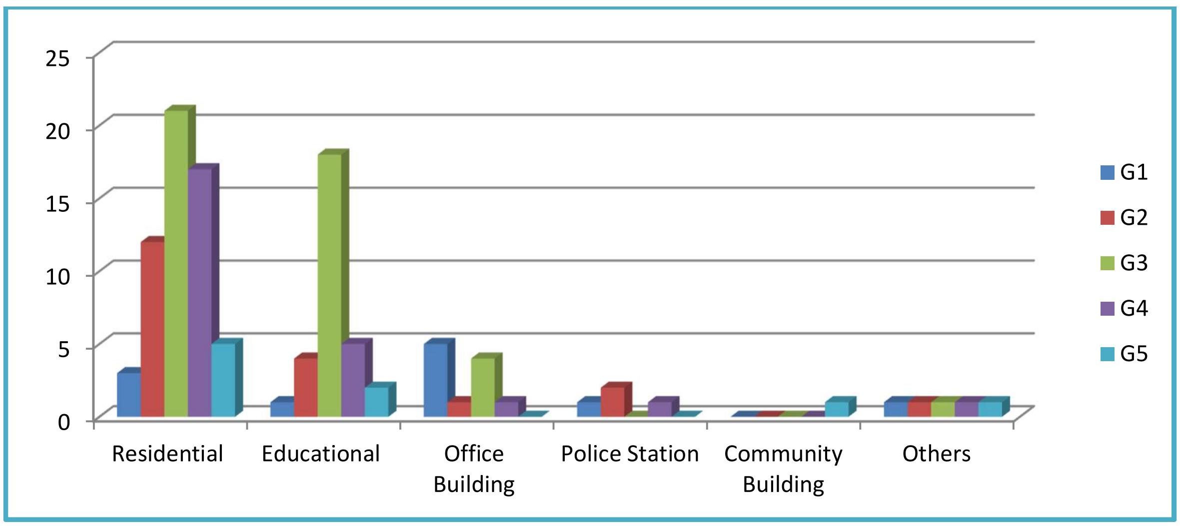

Figure 5:*Occupancy wise Buildings*

Where,
G1: Negligible to slight damage, G2: Moderate damage, G3: Substantial to heavy damage, G4: Very heavy damage, and G5: Destruction.

3.3 Existing Approaches

Jajakot is still rich in the tradition of buildings made up of local materials such as mud, stone, wood and bamboo, and corrugated galvanized sheets. The traditional materials are found at a cheaper rate, which are more ecological and safer during earthquakes. These materials are often used in combination to build temporary shelters, particularly in the wake of an earthquake. Community members also utilize traditional skills to construct houses and bridges using locally sourced materials. During the earthquake of 2023, the symmetrical buildings of 2 -3 stories of stone in mud mortar survived, whereas RCC buildings without following design guidelines were collapsed. Earthquake-safe "Building features" are still existed in some buildings due to the introduction of several earthquake features. Wooden posts, provision of bands, tundals, and a roof that is tightly held to the wall are examples of earthquake-resistant techniques that are still found in the traditional buildings

Figure 7: *Bamboo reinforcement for retrofitting*

Figure 6: *Use of Wedges to make the Wall Tight*

Figure 8: *Use of tundals and wooden posts*

4. Findings

The traditional knowledge within the setting can be rediscovered by closely studying the surviving buildings that represent this knowledge. The traditional skills are also getting lost because craftsman is changing to other occupations due to lack of demand. The continuous additions and alterations processes have made the survived traditional buildings more vulnerable to the earthquake. In relation to modern reinforced concrete structures, traditional buildings are the not bounded monolithic. Important elements used in traditional buildings are mud, stone and wood. Mud is very weak in strength as compared to the strength of brick and timber. In case of greater thrust the mud, mortar cracks and helps to displace wall thus absorbing the thrust. This causes partial collapse preventing total collapse of the building. In the same way, Traditional houses have many timber components like beams, joists, and lintels and pillars. The wooden members tie the brick walls, making them work as a single unit. It prevents the distortion or displacement of walls in case of an earthquake. The flexibility of wooden members can absorb some external forces by bending itself and return to its original shape after the force is released. It helps break the wall. Even in the case of breaking, the timber components prevent total collapse. However, in the urban context of Bheri municipality, the majority of the buildings are being replaced by modern reinforced concrete buildings in the limited space. Also, traditional materials are not easily available, which are getting more expensive, especially the availability of wood, and traditional craftsmen have changed their profession, and their capacity is getting lost. In the recent earthquake of 2023, the buildings collapsed due to the following causes:

The first one is buildings planned, conceived, and constructed by owners without any input from engineers. Buildings not designed by an engineer can have critical structural weaknesses leading to a serious collapse, which applies to most collapsed buildings in the recent earthquake.

Similarly, the second reason is buildings designed by an engineer but constructed differently; for example, to add extra floors on top of a building that has been designed as a 2-3-storey building. Similarly, the quality of materials (concrete and reinforcing steel) was found deficient in many buildings.

In this context, only one approach, i.e. indigenous approach, may not have a solution to reduce the earthquake vulnerabilities. In this urban context, the integration approach is suited to reduce the earthquake vulnerabilities, which are:

- **Engineering Approaches**
  - ✓ Use of a proper risk-sensitive land use plan
  - ✓ Zoning Regulation and Density Control
  - ✓ Mandatory Implementation of National Building Code and Building Bylaws
  - ✓ Improvement of existing infrastructures with retrofitting techniques

- **Indigenous Approaches**
  - ✓ Mandatory provision of open spaces in newly constructed buildings
  - ✓ Traditional techniques need to be preserved
  - ✓ Symmetrical in plan and axes building
  - ✓ The ratio of height to breadth of the house is less than or equal to 2
  - ✓ Conservation of three–layer wall construction
  - ✓ Use of Wedges and traditional construction tools and techniques
  - ✓ Use of traditional materials

In addition to the integration approach, earthquake risk reduction cannot be imagined without the dedicated involvement of the members of the local community living in the exposure area. Though social interaction between community members has reduced, the settlement is intact to some extent. The mutual support system might prove crucial in recovery after the earthquake through collective help and shared labour. Also, the neighborhoods in both settings that have high social capital, the reconstruction and rehabilitation become smooth and faster, with better collective decision making among the communities and better cooperation between the community and the local government. In addition, earthquake awareness is required that not only imparts the knowledge of risk reduction to the people but also convinces them of the benefits. The earthquake of 2023 has pointed out the need for multi-stakeholder cooperation, and the gap between knowledge and practice for reducing earthquake disasters. Innovative methods such as the shake table demonstration, annual Earthquake Safety Day, dialogue with various women's groups and local level governance at the neighborhood level, exhibition, mobile earthquake clinics, and recognition of the importance of trained masons are the innovative methods practiced for earthquake awareness. Therefore, community-level awareness and policy enforcement are needed to reduce the earthquake risk with the integration of engineering and indigenous approaches. The policy enforcement approach is applicable only on the strict implementation of planning norms and standards, Building bylaws/code, and a risk-sensitive land use plan.

In case of a rural setting in Jajarkot District (Barekot)**,** poor quality of construction of buildings and infrastructure was also observed as the main cause of structural vulnerability. Prevalence of non-engineered construction, poor quality control of materials, and construction mechanisms makes the construction poor enough even for normal Conditions. Lack of awareness and concentration of knowledge and skills only in academic centers contributes to the vulnerabilities.

In rural communities, individuals often employ local masons for construction work. These masons, though skilled in their craft, have received no formal training and rely on personal judgment, field experience, and guidance from more seasoned colleagues. With no dedicated vocational schools for masonry in both urban and rural contexts, the responsibility for many local construction endeavors falls on these craftsmen and their intuitive expertise.

In the above rural context, a large part of the communities belonging to low-income strata of the area, the locally available materials (i.e., mud, stone, and wood) make the communities both sustainable and affordable. To counteract the loss of local knowledge about traditional building techniques and materials, a system should be developed to keep the craftsmen in work and make sure their knowledge will be passed on next generations. In Barekot, where wood is easily available and the majority of the buildings are less than 3 stories with mud-mortar, the affected buildings can be retrofitted with the available local materials, eg, retrofitting with wood bands and corner strengthening with wood with new technology. The indigenous approach is appropriate for reducing the earthquake risk in the current context (Singh,2016).

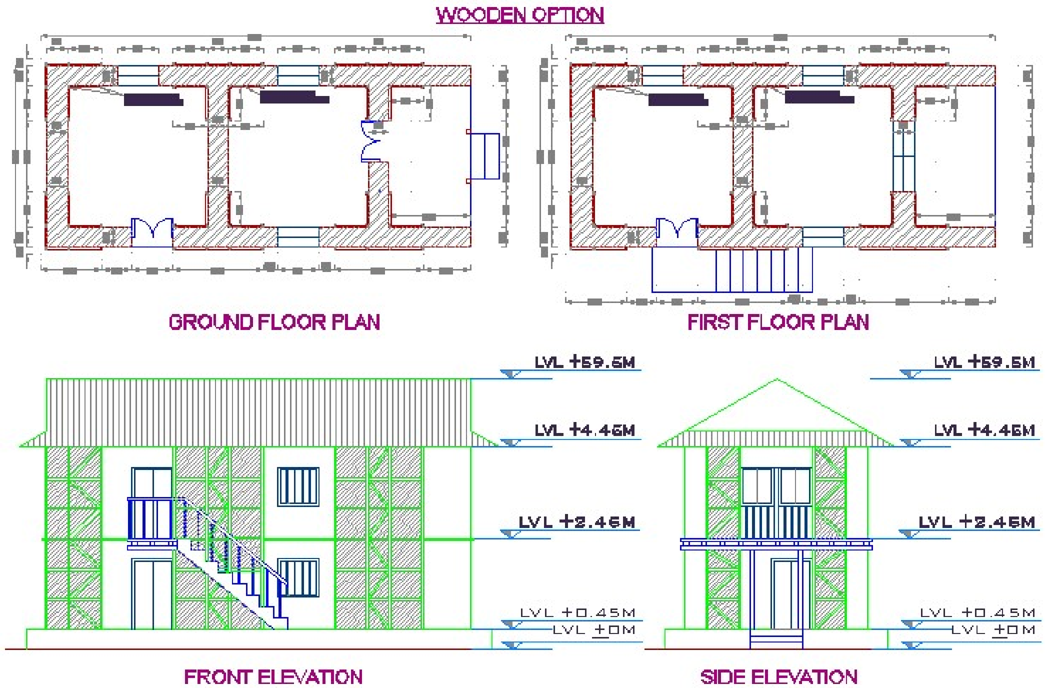

Figure 9: *Retrofitting with wood bands*

However, community level awareness, visionary planning and compact settlement are advantageous for reducing the earthquake. Implementation of planning norms and standard, building bylaws/code and risk sensitive land use plan will be supportive to reduce the earthquake disaster in the current changing context of rural setting.

In the findings of this study, following are four main issues for reducing the earthquake risk.

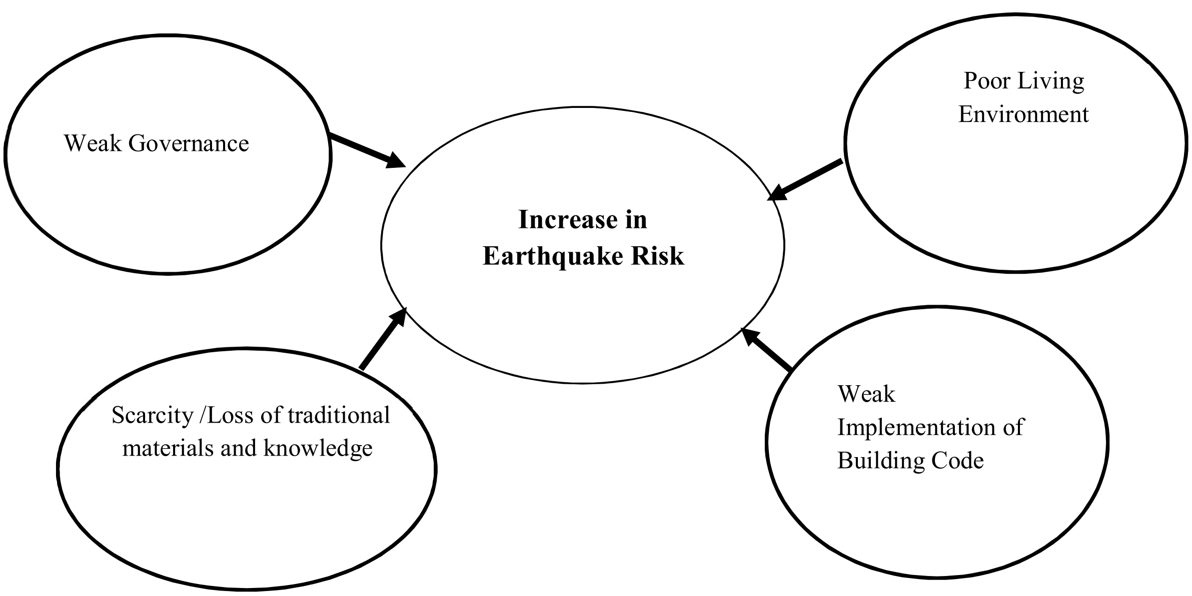

Figure 10: *Four main issues for reducing the earthquake risk*

Where,

Poor Living Environment = function (encroachment of open spaces, no or improper maintenance of individual buildings, more occupancy in individual buildings, vertical sub-division, addition of more floors, incompatible change, hanging electric wires, improper solid waste disposal, poor sanitation facilities).

Weak governance =function (lack of authority delegation to municipality and local community, no involvement of NGOs/CBOs, Weak public participation, lack of transparency, low ethics & unaccountability of government institutions).

Weak Implementation of Building Code =function (increase in the owner-built construction activities /construction without approved drawing or technical supervision)

In the rural setting, the following are the major issues observed for reducing the earthquake risk, which are mainly:

- Predominantly of Masonry Structure /Owner Built
- Low Income Strata/Question of Affordability/Sustainability
- Lack of Implementation of Building Code
- Scattered Settlement

5. Conclusion

Integration approach might be cost-effective and understood by people as well as accepted by the communities. Indigenous approach may not be the only solution, especially for the urban setting where the trend of construction of high-rise buildings is increasing and local materials and skills are scarce in the community. However, the integrating approach should not pose any threat to any individual, institution, or project. The combined approach is adaptive to local conditions.

Though numerous vulnerability reduction strategies exist, appropriate grassroots-level technology transfer initiatives should be put in place for creating awareness, appreciation, and application models for using disaster-resistant and cost-effective building technologies where a large part of the communities belong to low-income strata with non-engineering construction practices. The traditional skills for building demonstrate the use of local materials that are available locally, such as wood, mud, and stone. This makes them both sustainable as well as affordable for both rural and urban communities. In addition, the traditional morphology of the case study area might be fruitful for escape during the earthquake. In technological aspects, the local craftsmen play an essential role. Technicians and engineers have little control over the construction of owner-built buildings. Proper training of craftsmen can help build their confidence in using the technology and skills to construct safer buildings.

Retrofitting, an emerging area of technology using both indigenous and engineering techniques, might be useful for strengthening partly damaged or vulnerable buildings instead of rebuilding or reconstructing the buildings, especially in the built environment of the core urban setting. Small improvements in design and construction of buildings can make a large change to their overall earthquake resilience in the low/medium income community in case of rural setting. For example, instead of changing very high-strength construction material or applying higher technology in construction, stitching the walls, providing bands, tying roofs and floors, and vertical rods at corners, etc. In the second study area, where the majority of the buildings are masonry buildings where improving workmanship in case of frame structure buildings is more important than adopting new construction material. For this purpose, an environment should be created to involve resident members, the private and professional sectors, to play a major role in the earthquake risk reduction in both settings. The current policy should be realistic and emphasize the community-based approaches towards earthquake risk mitigation in the rural setting compared to the urban setting. As an important tributary of a broader sustainable development pathway, earthquake risk reduction must be integrated with the development process in the communities. It needs to be mixed up with the development process at different stages, and must become an integral part of the development activities. In the earthquake risk reduction process, a culture of safety can also be easily introduced if the communities are adequately educated, equipped, and resourceful through good governance. Through this study, it was found that people are not adequately aware of even simple disaster issues.

Therefore, we must shift the focus to the poorest and vulnerable sections of society, and ensure that the interventions are integrated with the integration of both approaches. Only one approach may not have the solution to reduce the earthquake vulnerability in the current urbanizing situation and insufficiency of local resources. However, the local solution searched within the social, cultural, and environmental framework for reducing earthquake risk will only be sustainable in the majority of poor communities, particularly in rural settings.

6. Recommendations

We must shift the focus to the poorest and vulnerable sections of society, and ensure that the interventions are integrated with the integration of both approaches. Only one approach may not have the solution to reduce the earthquake vulnerability in the current urbanizing situation and insufficiency of local resources. However, the local solution searched within the social, cultural, and environmental framework for reducing

Following are some recommendations:

- ✓ **Flexibility in Building Guidelines:** Building guidelines should be flexible in terms of design, construction techniques, and choice of materials, addition, and alteration to the traditional fabric. In addition, disaster mitigation laws, institutions, programs, and processes must anticipate unpredictable changes and be adaptable to new knowledge and conditions.

- ✓ **Networking among stakeholders:** Networking among different national and local organizations, including NGOS/INGOS, should be promoted to discourage overlaps and duplication in earthquake risk management. Functions and responsibilities must be formalized and accepted by all the involved entities.

- ✓ **Strengthening grassroots organizations:** To strengthen grassroots organizations and governance, the Disaster Mitigation Structure Committee should be established at the ward level, which would be effective in mobilizing the local people and resources at the tole level.

- ✓ **Address the challenge of decentralization:** In Nepal, there is a drive toward devolution of powers, authorities, and responsibilities from higher levels of government to lower levels of government. Municipality may not possess adequate resources, expertise, and political commitment, which must be developed through training and capacity-building programs.

- ✓ **Build sustainability:** We must always look beyond our current efforts, activities, or programs and develop strategies to ensure that interest and commitment are sustained.

References

1. Acharya, S., Bhattarai, S., & Shrestha, R. (2021). Cultural influences on disaster preparedness in Nepal. . *Journal of Risk Research, 24(2), 186–202. https://doi.org/10.1080/13669877.2020.1864001*.
2. ActionAid Nepal. (2018). *Community-Led Disaster Risk Reduction: Case Studies from Nepal.* Kathmandu: Action Aid Nepal.
3. Bhatta, M. and Sinha, A. (eds.) (1999), Addressing Vulnerability –Perspectives on Influencing Public Policy in South Asia, Report, Disaster Mitigation Institute with Natural Disaster Management Division of Department of Agriculture and Cooperation, Ministry of Agriculture Cooperation, Ministry of Agriculture, Government of India and Duryog Nivaran.
4. Bheri Municipality's Report on Post-2023(2024), Jajrkot earthquake Developemnts – Assessing Damages, Relief Efforts, Recovery Progress, Ongoing Needs and Emergency challenges
5. Blaikie, P., Canon, T., Davis, I. and Wisner, B. (1994), At Risk: Natural Hazards, People's Vulnerability and Disasters, Routledge, New York.
6. Cultural Atlas. (2017). *Traditional beliefs in Nepal*. Retrieved from https://culturalatlas.sbs.com.au/nepalese-culture/nepalese-culture-religion/?utm_source=chatgpt.com
7. Dixit, A.M. (2003), "The Community Based Program of NSET for Earthquake Disaster Mitigation", The International Conference on Total Disaster Risk Management, 2-4 December, Thialand, Bangkok.
8. DP Net, 2023, "Jajarkot Earthquake 2023,Ana analysis of Rescue,Relief and Early Recovery, Kathmandu.
9. Gautam, D. (2018). *Seismic Vulnerability and Rural Perceptions Post-Gorkha Earthquake.* . Earthquake Spectra, 34(4), 1523–1547.
10. Gautam, D., & Phaiju, A. G. (2020). Challenges and Opportunities in Post-Disaster Reconstruction in Rural Nepal. *International Journal of Disaster Risk Reduction, 49, 101657.*
11. Gellner, D. (2020). *Religion and natural disasters in Nepal*. Retrieved from https://dhi.hypotheses.org/9181?utm_source=chatgpt.com

12. Hasan, A. (2005), “Reconstruction of Earthquake Affected Areas”, City Press, Karachi, Pakistan.
13. JICA (2002), The Study on Earthquake Disaster Mitigation in the Kathmandu valley Kingdom of Nepal, Japan International Cooperation Agency (JICA) and Ministry of Home affairs, His Majesty’s Government of Nepal , Final report Vol-I, II,III & IV.
14. JICA. (2020). *Post-Earthquake Housing Reconstruction Assessment Report.* Kathmandu, Nepal: Japan International Cooperation Agency.
15. Jigyasu, R. (2002), Reducing Disaster vulnerability through local knowledge and capacity, The case of Earthquake Prone Rural Communities in India and Nepal, Dr.Ing. Thesis Town and Regional Planning (NTNU), Norway.
16. KVERMP (2000), Project Completion Report, under the Asian Urban Disaster Mitigation Program, Asian Disaster Preparedness Center, Bangkok, Thailand.
17. Kuban, R. and Carey, H.M. (2001), Community-wide Vulnerability and Capacity Assessment (CVCA), Office of Critical Infrastructure Protection and Emergency Preparedness, Canada.
18. Malikarjun Case. (2022). *Relationship Between the Divine and Nature in Nepal – the Malikarjun Case*. Retrieved from https://dhi.hypotheses.org/9181?utm_source=chatgpt.com: https://dhi.hypotheses.org/9181?utm_source=chatgpt.com
19. MERCER, J. and KELMAN, I. (2008): ‘Living with floods in Singas,Papua New Guinea’, in SHAW, R., UY, N. and BAUMVOLL,J. (eds): Indigenous Knowledge for Disaster Risk Reduction:Good Practices and Lessons Learned from Experiencesin the Asia-Pacific Region. UNISDR Secretariate Asia and the Pacific, Bangkok, pp. 46–51
20. MoHA. (2021). *Local Disaster and Climate Resilient Planning Guidelines (LDCRP).* Kathmandu: Ministry of Home Affairs.
21. NPC. (2016). *Nepal Earthquake 2015: Post Disaster Needs Assessment (PDNA). Kathmandu.* Kathmandu: National Planning Commission Nepal.
22. Paul, B. K., & Bhuiyan, R. H. (2010). *Urban earthquake preparedness in South Asia: Perception vs. action.* . Kathmandu, Nepal: Disaster Prevention and Management, 19(4), 480–494.
23. Rijal, D.; Poudel, R.; Adhikari, B. (2016). Perception and preparedness of people towards earthquakes in Nepal. *International Journal of Disaster Resilience in the Built Environment, 7(4), 334–350.*
24. Schilderman, T. (2004), “Adapting traditional shelter for disaster mitigation and reconstruction: experiences with community-based approaches”, Intermediate Technology Development Group, Schumacher Centre for Technology and Development, for Technology and Development, Bourton-on- Dunsmore,Rugby CV23 9QZ,UK.
25. Sharma, M., Khadka, D., & Singh, R. (2017). Traditional Housing and Earthquake Vulnerability in Rural Nepal. . *Building Research Journal, 65(2), 107–120.*
26. Singh, R.P. (2016), Reconciling indigenous and engineering approaches for earthquake risk reduction - urban and rural setting of Nepal , Ph.D. Thesis Civil Engineering (Dr. K.N. Modi University), India.

27. Subedi, S., & Hetény, G. (2021). *Representation of Earthquakes in Hindu Religion.* Kathmandu, Nepal: July 2021 Frontiers in Communication; DOI:10.3389/fcomm.2021.668086; License CC BY 4.0.
28. UNDP. (2019). *Resilient Communities: A Review of Disaster Risk Reduction Approaches in Nepal.* . Kathmandu, Nepal: United Nations Development Programme.
29. UNRCO, Nepal. (2023). *UN Resident Coordinator's Flash Updates on the Jajarkot Earthquake. https://nepal.un.org.* Kathmandu, Nepal: UN Resident Coordinator's Office (UNRCO Nepal).