Kathmandu University Journal of Science, Engineering and Technology, Vol. 18, No. 2, December 2024

Kathmandu University
Journal of Science, Engineering and Technology

Assessing building typology and seismic vulnerability of masonry structures built with government grant after 2015 Gorkha earthquake

Neshil Koirala[a], Niraj Raj Panta[a], Prajwol Adhikari*[a], Achyut Paudel[b], and Manoj Sharma Wagle[c]

[a]Department of Civil Engineering, IOE, Pashchimanchal Campus, Tribhuvan University, Nepal.
[b]Department of Urban Development And Building Construction, Nepal.
[c]Pokhara Metropolitan City, Nepal.

Abstract

This research investigates the current landscape of reconstructed building typologies and assesses the vulnerability of masonry buildings reconstructed through government grants post-earthquake. A seismic vulnerability assessment framework was applied to evaluate 325 houses in Siddhalek Gaupalika (Ward-1, Ward-2), formerly Nalang, VDC. An indexed-based system was employed to assign total vulnerability scores to individual buildings, facilitating the qualitative classification of vulnerability levels. Findings reveal that 58.2% of reconstructed buildings exhibit very low vulnerability, while less than 41.5% display low vulnerability, with 0.3% classified as moderate vulnerability. Spatial analysis utilizing GIS was conducted to interpret the index's distribution. Additionally, the research identifies major factors contributing to vulnerability across four categories: workmanship and age of building, geometry of building, structure, and seismic components. Recommendations are provided to mitigate vulnerability in reconstructed buildings, emphasizing measures that could have been implemented to reduce susceptibility.

Keywords: Seismic vulnerability; Building typology; Vulnerability index.

1. Introduction

The earthquakes that struck Nepal in 2015 had a profound impact on the country, affecting approximately 8 million people, which is nearly one-third of the population [1]. The majority of the damage was inflicted upon unreinforced masonry houses, which make up 58 percent of all housing construction in Nepal [2]. In response to the earthquake, the Government of Nepal divided the victims into two categories: those qualified for reconstruction and those qualified for retrofitting. Those eligible for reconstruction received NPR 300,000, while retrofitting beneficiaries were given NPR 100,000 [3]. Many individuals had already begun the process of rebuilding or repairing their homes in pursuit of safe shelter due to delay in the proper reconstruction plan from government after 2015 Gorkha earthquake [4]. To aid in the reconstruction efforts, the government issued various design catalogues and checklists. As these design catalogues also could not address the actual needs and intentions of the people they started to construct their buildings as usual without aligning to the new standards. As a result, buildings did not comply with the standards set by National Reconstruction Authority (NRA) and releasing grants became problematic [4]. The problem got amplified when field technicians were also incapable of fully understanding the norms of the NRA.

The seismic vulnerability assessment of reconstructed buildings is crucial for mitigating future risks of those reconstructed buildings. After the Gorkha earthquake, several post-earthquake studies have been published focusing on different aspects of reconstruction but their assessment to future seismic risk has not been carried out properly. This paper presents the seismic vulnerability assessment of those reconstructed building within the mentioned study area. Various methods, including analytical, experimental, and empirical approaches, have been employed to estimate seismic vulnerability . It involves the assessment of building using empirical approach.

The evaluation process is performed whether the newly built building in its existing condition has the desired seismic performance capability. This assessment involves qualitative and quantitative assessment. By providing numerical measures and field calculated data it helps in effectively managing and reducing vulnerability to earthquakes, thereby enhancing resilience, and minimising potential future impacts.

The assessment provides insights into the distribution of vulnerability levels across Ward 1 and Ward 2 of Siddhalek Rural Municipality previously, Nalang Village Development Committee which aims to assess the Vulnerability of residential buildings in the Village (Fig. 1). The research will assess the typology of these reconstructed houses and identify the factors contributing to their vulnerability. Particular focus is placed on Building characteristics, Geometric, Structural and Seismic components. Field surveys and visual inspections were employed to collect data on existing buildings.

2. Literature review

The 2015 Gorkha earthquake in Nepal highlighted the significant seismic vulnerability of residential masonry buildings, leading to widespread damage and loss of life. It underscored the

---

*Corresponding author. Email: prajwoladhikari999@gmail.com

Figure 1: Typical buildings in Nalang village.

need for a deeper understanding of seismic vulnerability to implement risk reduction strategies effectively and improve the resilience of earthquake-affected communities. This literature review examines existing research on the seismic vulnerability of masonry structures, particularly those reconstructed with government assistance, identifies key gaps in the current knowledge, and proposes a framework for assessing the effectiveness of government reconstruction schemes.

The effectiveness of post-disaster reconstruction schemes, particularly in the context of Nepal's 2015 earthquake, has been a focal point of many studies. A growing body of research has examined the seismic performance of residential masonry buildings constructed as part of government reconstruction programs. While several buildings have adopted earthquake-resistant techniques, many remain seismically vulnerable due to subpar construction practices and the sluggish implementation of reconstruction schemes by the government [5]. Non-engineered construction methods in high-risk seismic zones, particularly rural areas, have been highlighted as a pressing concern [6]. Buildings erected using traditional Stone in Mud Mortar (SSM) techniques, especially those built before the earthquake, have demonstrated significant seismic deficiencies [7]. Conversely, post-earthquake constructions that followed engineering guidelines and building codes showed improved seismic performance, indicating that properly implemented reconstruction schemes can enhance structural resilience.

In particular, post-disaster masonry buildings constructed after the 2015 earthquake have shown a range of seismic performances. Unreinforced masonry (URM) structures, for example, exhibited vulnerability due to inadequate structural integrity, high imposed loads, and material degradation over time [8]. In contrast, wooden frame structures demonstrated superior earthquake resistance, suggesting that traditional, well-engineered techniques remain highly effective. The vulnerability of SSM buildings constructed after the earthquake was significantly reduced when proper engineering codes were followed, showcasing the essential role of adherence to construction standards in enhancing structural safety.

However, these efforts must be viewed in the broader context of socio-economic challenges that influence reconstruction. Studies have revealed that rural areas were disproportionately affected by the earthquake, largely due to a lack of awareness and limited financial resources [1]. Delays in government reconstruction efforts left many individuals with no option but to rely on traditional construction methods, further weakening the seismic resilience of their homes [5]. These socio-economic factors, along with inadequate enforcement of modern building codes, heightened the vulnerability of post-disaster reconstructions in these regions.

To address these vulnerabilities, various seismic vulnerability assessment methods have been applied. The National Society for Earthquake Technology (NSET) guidelines have been widely used to evaluate the resilience of buildings [9]. Both qualitative and quantitative approaches have provided comprehensive insights into the vulnerability of these structures. Holistic methods such as vulnerability indices and structural testing techniques have played a key role in offering a nuanced understanding of the seismic risks faced by post-disaster buildings [5].

At the same time, the role of support from both governmental and non-governmental agencies has been critical in reconstruction. The Nepal Reconstruction Authority (NRA) was established to manage and coordinate post-earthquake reconstruction. Numerous non-governmental organizations (NGOs) and international agencies have worked under NRA's guidance to implement rebuilding programs and raise awareness about earthquake preparedness [10]. These collaborative efforts have been instrumental in the recovery process, underscoring the importance of coordinated actions in post-disaster settings [4].

This need for structural resilience and preservation extends to historic masonry structures, as seen in the seismic vulnerability assessment of Bindhyabasini Temple. Nepal's tectonic setting makes such structures highly susceptible to earthquake damage. Through systematic assessments combining qualitative (Rapid Visual Screening, Vulnerability Index) and quantitative (Ultrasonic Pulse Velocity, Rebound Hammer) methods, researchers identified the temple's vulnerability, particularly in critical areas such as openings and dome-wall connections. Recommendations for structural strengthening and continuous monitoring were proposed, offering crucial insights for safeguarding cultural heritage in seismically active regions, which can serve as a guide for future conservation efforts in Nepal [11].

Moreover, The FEMA P-154 guideline [12], provides a comprehensive methodology for assessing the seismic vulnerability of buildings using Rapid Visual Screening. This approach classifies buildings based on a variety of factors such as building material, height, irregularities in geometry, and condition of structural components. According to FEMA's approach, masonry buildings are typically assigned a vulnerability score based on their construction quality and compliance with seismic safety standards.

The literature highlights progress and challenges in improving the seismic resilience of masonry buildings post-2015. Despite reconstruction efforts, many buildings, especially in rural areas, remain at risk due to poor construction practices and socio-economic factors. Effective implementation of government guidelines and continuous monitoring are needed for long-term resilience. This study investigates the typologies and seismic vulnerabilities of government-funded reconstructed buildings, applying an index-based assessment to 325 houses in Siddhalek Gaupalika.

3. Methodology

In this study, the focus lies on employing a qualitative assessment method to assess the seismic vulnerability of reconstructed buildings. This method has been deemed the most effective and practical following a comprehensive review of existing methodologies. To initiate this process, the researchers aim to identify and categorize the diverse factors influencing the vulnerability of masonry structures. The research draws upon insights from a paper titled "An Empirical Method for Seismic Vulnerability Assessment of Nepali School Buildings" [6] to assist in the classification of factors influencing the vulnerability of masonry structures.

For the qualitative assessment to proceed, a suitable location with extensive reconstruction activities is necessary. After thorough exploration of potential sites, Nalang VDC has been identified as the ideal location for the study. As Nalang VDC of Dhading district witnessed a substantial number of building reconstructions post-earthquake. From 2015 Nepal Earthquake open data portal it is found that total of 909 houses [13] were reconstructed within this area, indicating a significant level of recovery and rebuilding efforts. From these total buildings we conducted a survey of 325

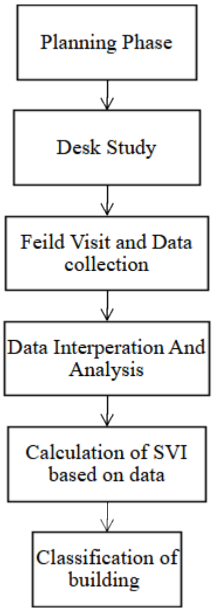

Figure 2: Flowchart of methodology.

houses.

The flowchart presented in Fig. 2, provides a comprehensive outline of the methodology employed in this study. It elucidates the sequential steps undertaken, from literature review to data analysis, ensuring a systematic approach to address the research objectives within the confines of this paper.

3.1. Qualitative assessment

In the implementation of the qualitative approach, the classification of different factors was guided by the paper titled "An Empirical Method for Seismic Vulnerability Assessment of Nepali School Buildings." [6]. However, since this paper covered both RCC and masonry structures, adjustments were necessary to exclude factors not applicable to masonry structures. This modification aimed to enhance the effectiveness of the assessment. Factors that were removed had their scores equally distributed among other factors within the same component. The revised factors and their respective scores, reflecting their vulnerability effects, are illustrated in Fig. 3.

The scoring for each factor was conducted on a scale ranging from 1 to 5, as per the classification outlined in the paper titled "An Empirical Method for Seismic Vulnerability Assessment of Nepali School Buildings." [6]. Factors were assessed based on their vulnerability condition, with a score of 1 indicating very low vulnerability and a score of 5 signifying high vulnerability. The data, ranging from 1 to 5, has been normalized to range of 0 to 1 using the min-max normalization method.

Modifications to the calculation method for total vulnerability have been implemented, as demonstrated by the revised calculation formula provided by [6]:

$$\text{TVI} = 0.2 \times (\text{Workmanship and age factor}) + 0.2 \times (\text{Geometric factor}) + 0.5 \times (\text{Structural factor}) + 0.1 \times (\text{Seismic component})$$

These adjustments were undertaken to improve the accuracy and comprehensiveness of the vulnerability assessment process.

By incorporating factors relevant to physical, economic, and social vulnerabilities, the aim is to offer a more holistic understanding of the overall vulnerability landscapes. The final vulnerability score is then normalized to a scale of 0 to 1, and the vulnerability class is classified as shown in Table 1.

3.2. Field survey

For the data collection process of our research, we visited the study area, Nalang village in the Dhading district (Fig. 4). We prepared a digital fill-up form using Kobo Toolbox software to collect the required data for vulnerability assessment. During the data collection process, we surveyed all 325 houses individually, filling out the form in chronological order. The form contains Name of owner, their ethnicity, location and all the required data that are required to calculate seismic vulnerability that is shown in Fig. 3.

Additionally, we conducted interviews with the locals, house owners, and contractors to gain in-depth information about the houses. These interviews provided insights into the construction practices used, which were crucial for determining the vulnerability of the houses. Furthermore, we gathered information about the infrastructure available during the construction period through these interviews. This comprehensive approach ensured that we collected detailed and accurate data for our assessment.

4. Results and discussion

4.1. Building typology

In the study, out of 909 reconstructed houses in the village [13], 325 houses were chosen for seismic vulnerability calculation. During the observation period, it was observed that 74% were brick in cement, 18% were stone in mud, 1% were hollow concrete block, and 7% were either brick in mud or stone in cement showing brick in masonry as most used material for construction as shown in Fig. 5.

4.2. Vulnerability factors

Among the 325 houses observed , as shown in Fig. 6, it was discovered that 41.5% exhibited a low vulnerability level, indicating significant risk factors such as structural weaknesses and inadequate disaster preparedness measures. Conversely, 58.2% of the houses demonstrated very low vulnerability, suggesting a higher level of preparedness for potential hazards, including better construction practices and adherence to safety standards. However, one house fell into the moderately vulnerable category, prompting concerns about critical vulnerabilities within the community. This particular house may have structural deficiencies or lack essential safety features, highlighting the need for immediate attention and remediation.

These findings highlight the need for focused efforts, especially for homes at higher risk. Knowing these vulnerability levels helps in deciding where to allocate resources and how to plan specific actions to improve resilience and reduce risks. This analysis is crucial for making the community safer and better prepared for potential hazards.

4.2.1. Workmanship and building age

Under the category of workmanship and building age, the analysis revealed varying levels of vulnerability among the surveyed structures. Specifically, 69% were classified as very low vulnerable, indicating a high degree of resilience. Meanwhile, 24% were categorized as low vulnerability, suggesting some susceptibility to risk factors. A smaller subset comprising 3% exhibited moderate vulnerability, while 1% were classified as very high vulnerable, indicating significant risk exposure.

The inadequate thickness of reinforcement bands observed in the houses significantly enhances seismic vulnerability as shown in Fig. 7. This is further exacerbated by incorrect orientation of gable bands; they are most susceptible during seismic events. In addition, a missing Damp Proof Course (DPC) facilitates the travel of ground moisture into the superstructure as shown in Fig. 8. This migration

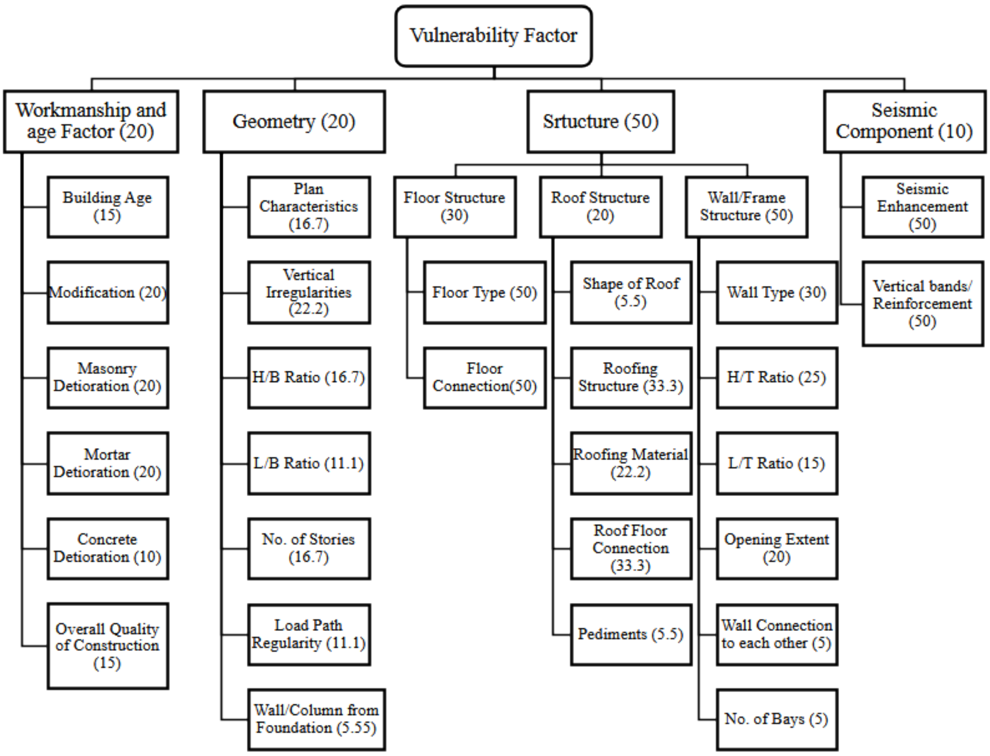

Figure 3: Vulnerability Score and Component Classification [6].

Table 1: Classification of Vulnerability Score to Vulnerability Class [6].

Vulnerability Score	Vulnerability Class	Description
0-0.17	Very low	No severe damage expected even at very strong shaking, some minor damage to infill walls and non-structural components
0.17-0.34	Low	Most buildings are not damaged, some suffer minor non-structural damage at moderate to strong shaking but no structural damage at strong to very strong shaking
0.34-0.49	Moderate	Many buildings suffer minor non-structural damage at moderate shaking, many buildings suffer serious damage to infill walls at moderate shaking, few buildings suffer structural damage at strong shaking, no collapse at very strong shaking
0.49-0.59	High	Some buildings suffer major structural damage at moderate shaking, infill walls are severely damaged, widespread non-structural damage at moderate shaking, some buildings partially collapse at strong shaking, many buildings need extensive repair/retrofit after moderate to strong shaking
0.59-1	Very High	More frequent major structural damage at moderate shaking, many buildings are near collapse at strong shaking, severe and widespread damage to infill walls and non-structural components.

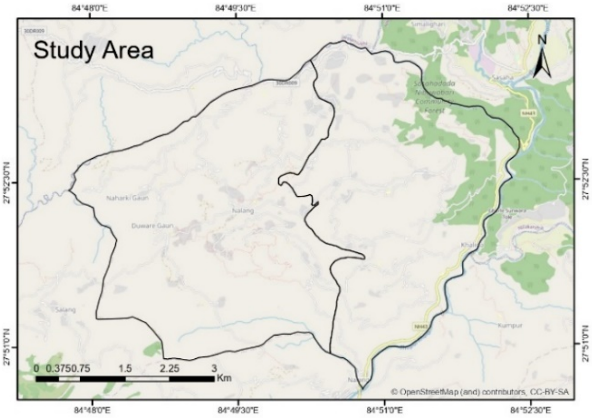

Figure 4: Study area: Nalang village.

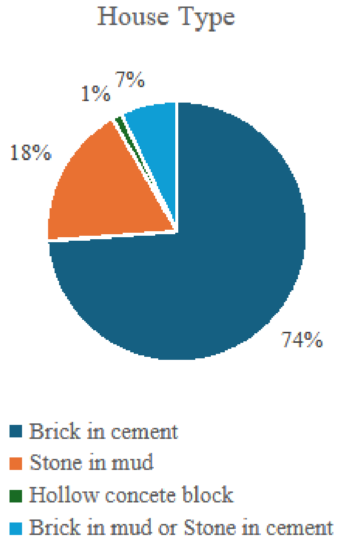

Figure 5: Pi-Chart of building typology.

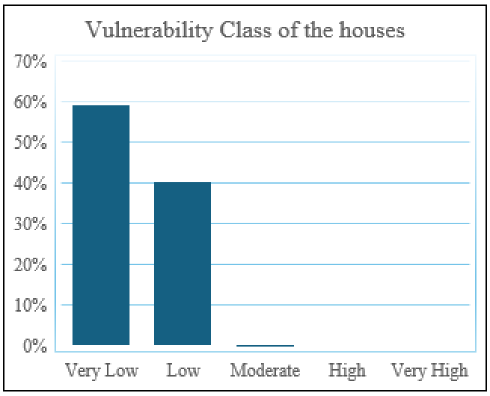

Figure 6: Classification of buildings according to their vulnerability class.

Figure 7: Improper band thickness and lack of gable band.

Figure 8: Inappropriate DPC results in mould formation.

of moisture leads to mold formation, which is not only harmful for the superstructure in losing its strength and integrity but is also ominous from a health perspective [14]. If mold can weaken building materials over time, it will lead to health concerns for people using that facility. That makes the correct method of construction and a proper moisture-control technique quite indispensable in its importance.

Significant discrepancies in workmanship quality have been observed, which can be attributed to insufficient training in reconstruction practices. This gap in training leads to variations in the execution of reconstruction tasks, resulting in inconsistent quality and standards. Addressing these training deficiencies is essential to improve the overall quality and consistency of workmanship in reconstruction projects.

4.2.2. Geometry

The architectural analysis revealed that the majority of buildings in the studied area exhibit rectangular, square, or L-shaped configurations. Walls typically possess thicknesses ranging from 250 to 350 mm for brick structures and 350 to 450 mm for stone constructions. Regarding building height, most structures consist of a single story, with some featuring attics. Notably, a subset of buildings has undergone a change in occupancy from residential to commercial, resulting in the creation of soft stories, often characterized by ground-level shutters. These findings provide critical insights into the architectural diversity and adaptive reuse trends within the surveyed community, informing strategies for risk assessment and disaster preparedness initiatives.

Figure 9: Surveyed houses of stone in cement, brick in cement and hollow concrete material.

4.2.3. Structure

Under the structural factor, the examination focused on three components: roof structure, wall/frame structure, and floor structure (Fig. 9).

Concerning roof structure, it was found that the majority of buildings 74.2% feature double-pitch roofs, while 21.8% have single-pitch roofs. Timber is commonly utilized for construction, with corrugated galvanized iron (CGI) as CGI sheets are lightweight and flexible, allowing them to absorb and dissipate energy more efficiently. This makes them less vulnerable to seismic forces compared to slate or clay roofing. Additionally, CGI sheets are cost-effective, which is why the majority of houses are built with CGI roofing. In terms of vulnerability, 2% of houses were classified as very low vulnerable, 84% as low, 13% as moderate and 1% buildings as high vulnerable.

In assessing wall/frame structure, factors such as wall type, height-to-thickness ratio, length-to-thickness ratio, openings, and connections between walls were considered. Walls constructed with brick in cement are less vulnerable, whereas those built with stone in mud or mortar are more vulnerable. According to the recommendation cited in [15], the use of hollow concrete walls is suggested to enhance structural integrity Although a high height-to-thickness ratio is a vulnerability factor, the length-to-thickness ratio is generally well maintained.

Regarding floor structure, the predominance of single-story buildings did not significantly affect vulnerability. However, for buildings with more than one story or an attic, the practice of placing floor structures directly on masonry walls was observed. Ensuring a robust connection between the floor and the wall in a building significantly enhances its seismic vulnerability.

4.2.4. Seismic resilience component

During the construction process, both horizontal and vertical bands /reinforcements were incorporated into the building structure. However, it was observed that the bands provided did not meet the thickness requirements outlined in the Nepal National Building Code (NBC) 202:2015 Guidelines On: Load Bearing Masonry [16]. Furthermore, in certain masonry constructions, gable bands were omitted before laying the roof structure, potentially compromising the structural integrity (Fig. 11). To support the structure against seismic forces, vertical reinforcement was concentrated at building corners and near openings (see Fig. 10). These measures aimed to enhance the overall stability and resilience of the buildings, albeit with variations in adherence to established standards and practices.

4.3. Spatial interpretation

The vulnerability index map illustrates consistent vulnerability scores within specific areas but varies across different regions as shown in Fig. 12. This emphasizes the necessity for tailored interventions addressing the unique vulnerabilities in each locality. Houses marked in green indicate very low vulnerability, with three shades of light green representing intervals. Similarly, houses in the low vulnerability category are divided into three intervals denoted by shades of yellow, brown, and dark brown. It's notable that houses in yellow may easily transition to the very low vulnerability zone with recommended adjustments. Conversely, those in dark brown are at higher risk of transitioning to high vulnerability status, reflecting a vulnerability gradient within the mapped area.

Figure 10: Reconstructed house without roof and visible vertical reinforcement.

Figure 11: Poor roof to wall connection .

The construction quality in the area was compromised due to the lack of accessible road networks, which hinders the transportation of construction materials. This limitation results in buildings that exhibit low vulnerability to seismic activity. Additionally, the deficiency in proper training for workers regarding the reconstruction of buildings further exacerbates this issue, contributing to the low vulnerability status rather than achieving very low vulnerability.

Buildings with low vulnerability house residents who have steady jobs and savings, strong community support, and easy access to healthcare, schools, and emergency services, which helps them handle crises better. In contrast, buildings with very low vulnerability accommodate residents with substantial financial stability and multiple sources of income, well-organized community groups with clear emergency plans, and quick access to all necessary services, allowing them to recover quickly from any disruption.

4.4. Comparison with RVS-based vulnerability assessment methods

In order to validate the findings of the current study, which shows that 58% of the reconstructed masonry houses in Nalang exhibit very low vulnerability and 42% show low vulnerability, this section compares these results with vulnerability assessments based on the Rapid Visual Screening (RVS) methodology, particularly those adopted by FEMA. The purpose of this comparison is to evaluate how the results from this study align with globally recognized seismic vulnerability assessment methods.

In FEMA's studies, a significant portion of masonry buildings often falls into the low-to-moderate vulnerability categories, especially when there are concerns about non-compliance with modern seismic codes or inadequate reinforcement [12]

Vulnerability classification used in FEMA's RVS system provides

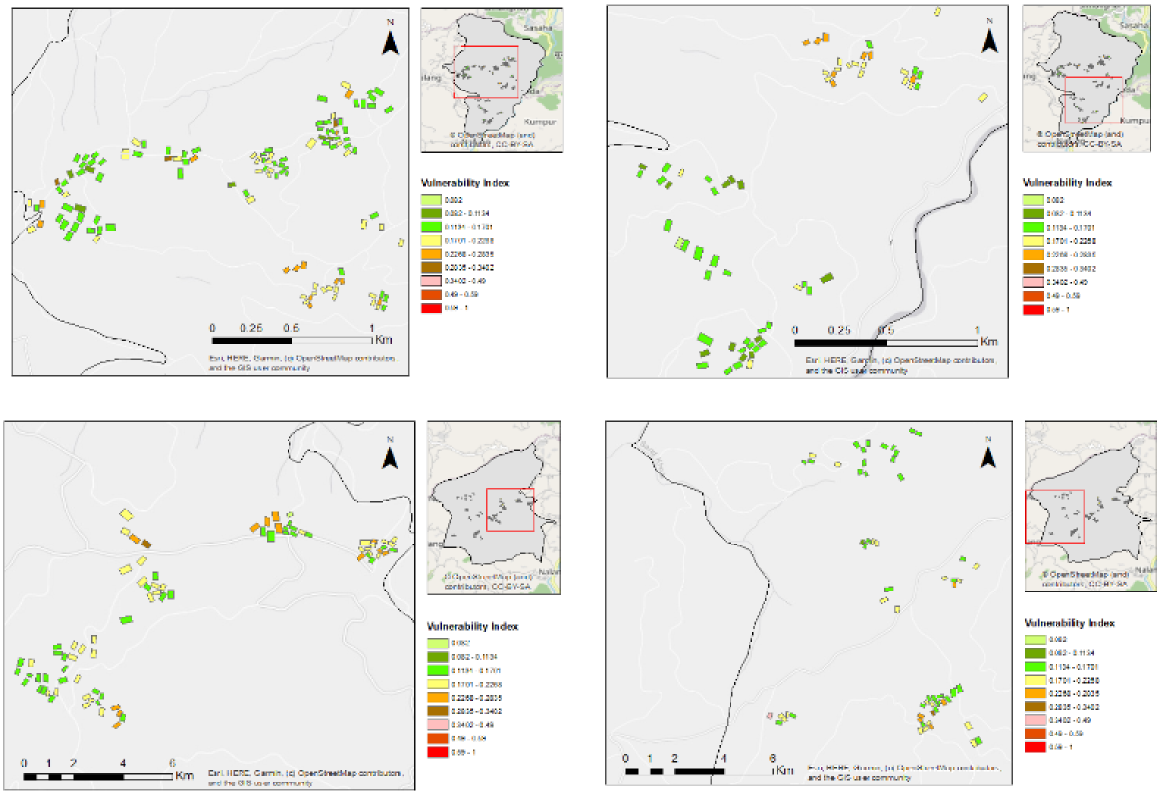

Figure 12: Seismic Vulnerability index map of Nalang Village.

a direct comparison with the findings of this study. The 58% of buildings in Nalang identified as having very low vulnerability align with FEMA's classification of well-maintained masonry buildings that are constructed or retrofitted in compliance with modern seismic standards. However, the 42% of buildings with low vulnerability may indicate areas where construction techniques, building materials, or seismic reinforcements could be improved, as seen in FEMA's studies on buildings with weak structural elements.

The findings are consistent with studies conducted in other seismic regions where the vulnerability of reconstructed buildings was similarly assessed. For instance, in Vienna, a study assessing seismic vulnerability of brick-masonry buildings reported that a considerable portion of buildings reconstructed after prior seismic events exhibited low vulnerability, although some showed higher vulnerability due to structural deficiencies [17].

These studies collectively validate the findings from the Nalang case, indicating that while a large proportion of reconstructed buildings typically exhibit low vulnerability, the specific vulnerability of each building can still vary, influenced by factors such as building typology, seismic components, and adherence to seismic standards.

5. Conclusion

In conclusion, the seismic vulnerability of buildings in Nalang has been effectively assessed through the qualitative assessment of 325 houses, focusing on building typologies, workmanship, age, geometry, structural components, and compliance with seismic standards. The analysis shows that 58.2% of reconstructed buildings have very low vulnerability, while less than 41.5% are categorized as having low vulnerability, with only 0.3% being moderately vulnerable. GIS-based spatial analysis was used to map and interpret the distribution of the vulnerability index across the region. Key factors influencing vulnerability include wall thickness, building shape, roof type, and structural integrity, with inadequate seismic components being a critical issue. Spatial interpretation indicated varying levels of risk across different regions. Enhancing construction practices, ensuring adherence to seismic standards, and targeting at-risk buildings will significantly improve seismic resilience in Nalang.

Acknowledgments

Special thanks are due to Mandip Shrestha for his invaluable assistance during the data collection phase. We express our sincere appreciation to the Research Management Cell, Pashchimanchal Campus, for their generous funding support. We also extend our gratitude to Dr. Shreedhar Khakurel for his valuable suggestions to enhance our results.

Author contributions

Neshil Koirala, Niraj Raj Panta, and Prajwol Adhikari contributed equally to this work. Achyut Paudel provided comprehensive supervision, contributing significantly from the conceptualization of the study to its finalization. Manoj Sharma Wagle offered valuable guidance on specific research aspects, enhancing the depth and quality of the work.

References

[1] "Post. *Disaster Needs Assessment*, vol. A. " Government of Nepal National Planning Commission Singha Durbar, Kathmandu (2015).

[2] "Post. Disaster needs assessment (2015). " Government of Nepal National Planning Commission Singha Durbar, Kathmandu, Available: www.npc.gov.np.

[3] Foundation T A & Government N. Distribution of earthquake reconstruction cash grants for private houses (2016). URL https://asiafoundation.org/publication/nepal-government-distribution-earthquake//-reconstruction-cash-grants-private-houses/, accessed: Nov. 29, 2024.

[4] "Post. *Disaster Recovery Framework.* " National Reconstruction Authority Government of Nepal (2016).

[5] Tamang T, Ramtel P, Shrestha J & Bhattarai P. Qualitative evaluation of reconstructed masonry residential building after the gorkha earthquake 2015 in rural areas of nepal: A case study at bhalche, nuwakot structural systems and energy efficiencies in low rise residential buildings view project effect of water content on workability view project (2023). URL https://www.researchgate.net/publication/369968581.

[6] Gautam D, Adhikari R, Rupakhety R & Koirala P, An empirical method for seismic vulnerability assessment of nepali school buildings, *Bulletin of Earthquake Engineering*, 18(13) (2020) 5965–5982. https://doi.org/10.1007/s10518-020-00922-z.

[7] Adhikari R K & D'Ayala D, 2015 nepal earthquake: seismic performance and post-earthquake reconstruction of stone in mud mortar masonry buildings, *Bulletin of Earthquake Engineering*, 18(8) (2020) 3863–3896. https://doi.org/10.1007/S10518-020-00834-Y/FIGURES/29.

[8] Gautam D, Rodrigues H, Bhetwal K K, Neupane P & Sanada Y, Common structural and construction deficiencies of nepalese buildings, *Innovative Infrastructure Solutions*, 1(1) (2016) 1–18. https://doi.org/10.1007/S41062-016-0001-3/FIGURES/16.

[9] Guragain R, Shrestha H & Kandel R C. Seismic vulnerability evaluation guidelines for private and public buildings (2009).

[10] Acharya P, Sharma K, Pokharel G R & Adhikari R, Managing postdisaster reconstruction after the 2015 gorkha, nepal earthquake and lessons learned, *Nat Hazards Rev*, 23(4) (2022) 04022029. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000585.

[11] Upadhyay M et al. Seismic vulnerability assessment of historic masonry structure: A case study of bindhyabasini temple (2024). URL https://conference.ioe.edu.np/publications/ioegc15/IOEGC-15-032-C2-5-80.pdf, accessed: Oct. 16.

[12] Council A T. Rapid visual screening of buildings for potential seismic hazards: A handbook (2015). Available: www.ATCouncil.org.

[13] "2015. Nepal earthquake: Open data portal (2024). URL https://eq2015.npc.gov.np/#/download, accessed: Apr. 20.

[14] Partners L N & Davidsonville M. Building moisture and durability past, present and future work (2004). URL https://www.huduser.gov/Publications/pdf/BuildingMoistureandDurability.pdf, washington, D. C., . Accessed: Oct. 05, 2024.

[15] Buch S H & Bhat D M, Performance of hollow concrete block masonry under lateral loads, *Advances in Structural Engineering: Materials* (2015) 2435–2444. https://doi.org/10.1007/978-81-322-2187-6_186. Volume Three.

[16] Nbc:202 N N B C (2015).

[17] Achs G & Adam C, Rapid seismic evaluation of historic brick-masonry buildings in vienna (austria) based on visual screening, *Bulletin of Earthquake Engineering*, 10(6) (2012) 1833–1856. https://doi.org/10.1007/S10518-012-9376-5/METRICS.