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Qualitative Evaluation of Reconstructed Masonry Residential Building after the Gorkha Earthquake 2015 in Rural Areas of Nepal: A Case Study at Bhalche, Nuwakot

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Abstract:
Unreinforced Masonry buildings (URMs) were the most prevalent construction practice in the rural areas of Nepal. During the 2015 Gorkha earthquake, most of these buildings suffered critical damage. Consequently, after the disaster, National Reconstruction Authority (NRA) was established to provide technical and financial assistance in the reconstruction process. This paper provides a qualitative framework for the assessment of masonry residential buildings in rural areas, considering the NRA minimum requirement, with Bhalche, Nuwakot as the study area. Rapid Visual Screening (RVS) and Key Informant Survey (KIS) were used to study, inspect and collect data and obtained results are compared with NRA minimum guidelines and Codal provisions. The study focuses only on a small but representative sample of reconstructed buildings rather than every building, with how and why of a particular issue rather than how many. The examination found that the reconstructed buildings in Bhalche have minor noncompliance issues, while significant non-compliance issues are found in all the houses constructed before the Government of Nepal's(GON) initiatives for reconstruction by the local people themselves using available local resources and existing knowledge. The KIS and RVS results are supported by case study examples and photos, respectively. The study also reviews the current building typology in Bhalche and attempts to delineate the rationale contributing to the undesired discrepancy in reconstructed buildings.

Keywords: Gorkha earthquake 2015, Key informant survey, Non-compliance, Rapid visual assessment, Reconstruction

1.Introduction

The Himalayan range formed by the collision between Indian Continent and the Eurasia plate, with its ever-rising nature, is under constant stress. This stress builds up with time and eventually gets released as an earthquake [1, 24]. Nepal, situated in the central part of the Himalayan chain, is highly prone to seismic hazards since most of the country is under Modified Mercalli Intensity (MMI) IX and X for the generally accepted recurrence period [22]. Nepal had experienced many historical events of the damaging earthquakes [14]. The 1255AD earthquake is the oldest major documented seismic event in Nepal; with ML7.8 on the Richter scale, the earthquake killed around one-third of the population in the Kathmandu valley. The country has since experienced frequent seismic events. April 25, 2015 earthquake is the most prominent with moment magnitude Mw 7.8, and Barkpak, Gorkha district as its epicenter [1, 14].This seismic event was followed by 672 aftershocks as of March 2016, including four aftershocks with magnitudes greater than Mw 6.0.Among the 77 districts in the country, 31 were affected by the Gorkha earthquake 2015, out of which 14 were declared crisis hit [14]. As the disaster occurred, the destruction was widespread, covering the life, property, and infrastructure situated in the affected area. The earthquake affected an estimated 8 million people's lives while causing 8790 casualties and 22300 injuries. Destroying more than half a million houses and many cultural heritage structures, the overall damage was estimated to be NRS 706 billion [11]. Rural areas were particularly more distressed due to vulnerable non-engineered infrastructure with their low resilience to seismic shock. The lack of seismic design and code implementation alongside poor construction made the destruction unavoidable. 4,98,852 houses were completely damaged, and 2,56,697 houses were partly damaged; on these data, low-strength masonry buildings comprised 95% of the total collapsed and 67.7 % of partially collapsed buildings[10].

After the catastrophic event, a damage assessment by the Central Bureau of Statistics (CBS) in coordination with the NRA was initiated to provide grant money to the victims for the reconstruction and restoration of the affected residential buildings. As post-disaster reconstruction requires multi-sectoral participation, significant resourcing, and a wide range of experts and personnel, Nepal Rural Housing Reconstruction Program (RHRP) was also established to assist the household in rebuilding earthquake-safe homes. NRA proposed NRs 3,00,000 as a monetary incentive dispersed in three installments, accompanied by technical assistance to all the eligible beneficiaries [11]. Likewise, a design catalog was published by NRA in 2015, with a typical layout like a living room, kitchen room, and bathroom to provide a standard house for reconstruction [20,2]. However, many people seeking shelter started reconstructing and repairing their homes before NRA's proper intervention, whereas in another case, due to low monetary incentives, many people were reluctant to build earthquake-resistant houses as per the NRA guidelines. Moreover, there seems to be a different expectation in rural areas. Many assumed the grant provided was for the total cost of reconstruction which was opposed to the NRA-accredited NRs 6,00,000, excluding the transportation expense, as the minimum expense for constructing an earthquake-resilient house [12].

Due to substandard construction practices like lack of integrity, inferior construction quality, foundation type, poor connection between walls, heavy mass, structural deficiency and non-engineered construction techniques are the major reason for the destruction of URMs buildings in the Gorkha earthquake 2015 M_w7.8 [27]. Stone masonry in mud mortar (SMM) houses was in a dejected condition in the different parts of Nepal, twain constructed before and after the Gorkha earthquake 2015 due to the non-engineered construction culture in the past and ignoring the minimum design requisite [26].Building code non –compliance issues in the Dhading district affects 15.2 % of the beneficiraies for receiving tranches, with 4.01% of the building constructed without following minimum guideline [23].In response to this type of compliance issue, NRA recruited 27 structural engineers as support engineers for 14 crisis-hit districts to provide additional assistance to alleviate construction discrepancies[23]. But considering the extensive rural area with difficult road access and the correspondingly large number of reconstructed houses, this seems highly ambitious. Nevertheless, as of October 2021, HRRP reported 866207overall beneficiers, 704341 had taken the third instalment, 47906 households(HHs) eligible for rettrofiting, and the remaining works were handed to the National Disaster Risk Reduction and Management Authority(NDRRMA) [19,28].The post-earthquake reconstruction produced houses that were inappropriate for their intended use disregarded local realities of rural living and substituted native traditional design and construction technologies with concrete houses that were inadequate in terms of space, climate, and practicality. [30].Sharma et.al [29] have also highlighted huge challenges for reconstruction such as insufficiency of coordination, political matters, and dearth of material and human resources. Also, the study by Chengqing et.al [31] founds that a region near the doors and windows areas are most vulnerable. There are few studies regarding residential masonry building-especially in a back warded rural area in terms of ethnicity, geology, economic and educational status-as people and infrastructure in these areas are comparatively more vulnerable than others. If these reconstructed buildings don't affirm the required seismic resilience, it can lead to another catastrophic event in a future earthquake Therefore, a systematic approach to evaluate the reconstructed houses is needed, The assessment would provide two benefits: First, this would help to acknowledge the risk and vulnerability attained by the people in a specific region, and second, beneficiaries' feedback provided in the study can help the respective authorities to understand the rationale behind the widespread construction inconsistency. Concomitantly, this lesson can provide a means to make better plans in the advent of future disasters.

The objective in this context, this paper gives a tentative framework for a surface-level inspection of reconstructed masonry buildings in rural areas through Rapid Visual Screening (RVS) concerning the minimum requirement enjoined by NRA. Moreover, the paper assisted by Key Informant Survey (KIS), helps examine NRA's involvement in reconstruction and identifies motives behind the construction incompetency from the beneficiary's perspective. However, the study is limited to the examination of the buildings which were designed for only residential masonry reconstructed buildings. Residential masonry buildings in rural areas had previously endured immense damage in the earthquake due to the owner's authority on the construction. Likewise, they also faced difficulties in knowledge transfer and receiving grants. So, for these reasons, the focus was concentrated on these areas. The authors have selected Bhalche, a rural ward in the Nuwakot district with major masonry building construction, as the case study for the assessment.

2. Methodologies

2.1 Conceptual Framework

Risk Assessment in this study involves analyzing the vulnerability and exposure of the structures to predict the probable damage and loss attained by the building in a future earthquake. This assessment is critical for disaster preparedness and especially important for masonry buildings due to their lack of performance in the past. The method and procedure for every building depend on different criteria according to the building's dimension, structural system, design method, seismic zone location, ground condition, and surrounding structures. With conservative research objectives limited to residential masonry buildings, two qualitative approaches were used for this purpose: RVS and KIS.

2.1.1 Rapid Visual Screening

RVS is a simplified method for the vulnerability assessment of buildings through visual inspection. It helps to identify and prioritize potentially risky structures for further detailed evaluation [13]. RVS is preferred due to its inherent fast nature to inventory, identify, and screen large stocks of buildings for potential seismic risks [9]. The procedure includes a reconnaissance survey for data collection as per the prepared checklist compliant with standards. An engineer or technician familiar with building construction and damage inspection is appointed to collect this information. The inspection process comprises a sidewalk survey observing the buildings from the exterior, and interior if possible, with a simultaneous entry in the checklist [9]. The survey requires 15-30 minutes for each building. The format for data collection includes identification information, structural features, non-structural features and site condition of the building, and occupant's characteristics. These data form the base for the building classification according to their risk [9, 13]. Figure1 is the diagrammatic representation of RVS and its components used for the study.

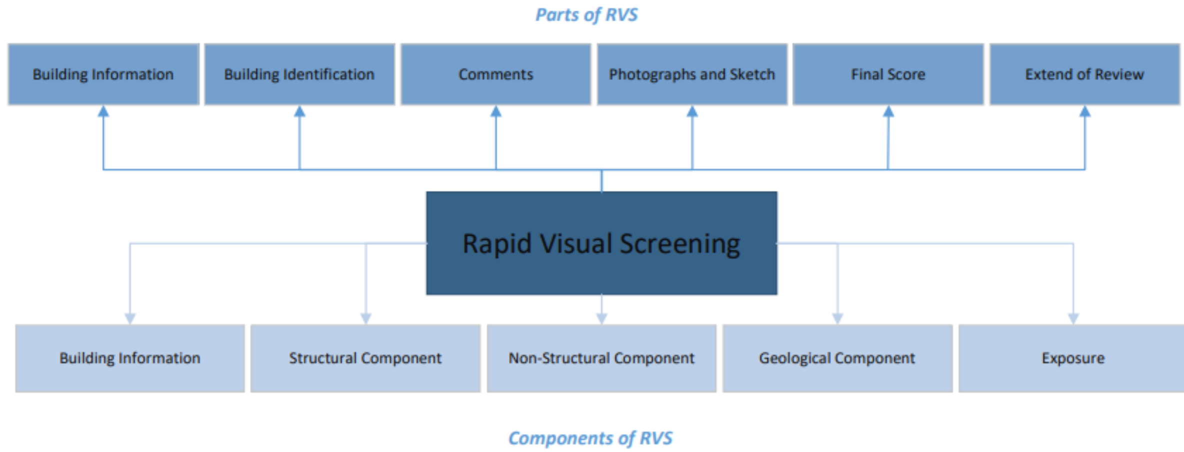

Figure 1: Diagrammatic Representation for Rapid Visual Screening

2.1.2 Development of Checklist

Federal Emergency Management Agency (FEMA) provides many guidelines for preparing the RVS procedures. This particular study referred to "Rapid Visual Screening of Buildings for Potential Seismic Hazard: A Handbook" [9]. The authors exploited the guidelines in the handbook to develop a comprehensive data collection checklist for the technical inspection. Likewise, for the inspection criteria, the minimum requirements for seismic resilient rural housing from the NRA's flexible design catalog-"Design Catalogue for Reconstruction of Earthquake House Volume I" [17] and "Design Catalogue for Reconstruction of Earthquake House Volume II"[6] made in compliance with the revised National Building Code (NBC)NBC 202[15]and NBC 203 [16] were referred. These critical technical requirements were considered the standards for reconstructed buildings assessment. The conventional RVS uses building age, construction type, and structural irregularity for attributing scores and evaluating the building risk category [9]. However, since all the reconstructed buildings are freshly built masonry buildings following the NRA model symmetrical layout, the scoring section for structure risk classification was skipped. Instead, this study prioritizes a compliance approach- every house which adheres to the minimum technical requirement, as stated by NRA, automatically qualifies for seismic resilient building.

2.1.3 Key Informant Surveys (KIS)

KIS, a qualitative process, is designed to provide in-depth information and contemplated views on open-ended questions from the identified knowledgeable people on a particular subject. The data drawn from the locals give rich, varied, and textured data attributed to their attitudes toward the study objective. The data can help in emphasizing the discrepancy between the expected and reality. In addition, build a collaborative database for future project planning [8]. KIS was used directly to get firsthand information on reconstruction from the locals. The knowledge can help understand NRA’s involvement in different reconstruction phases and identify influencing characteristics. The data collection was divided into four subsections; Beneficiaries Classification and Tranche Distribution; Transfer of Knowledge; Inspection in Ongoing Construction; and Post Construction Evaluation.

2.2 Sampling

The study is concerned with qualitative rather than a quantitative evaluation of reconstruction. The main objective of the research is to understand the pattern of non-compliance, if any, in the reconstructed buildings. Therefore, the study focuses only on the how and why of a particular issue rather than how many. In simple words, the study focuses on a small but representative sample of reconstructed buildings rather than every building. The significant advantage of this study is the feasibility to perform on a small scale and with minimum funding. Considering the qualitative nature, a set comprising each representative sample is adequate for the study [3, 7]. For the sample set; Stratified Purposive Sampling is the most appropriate method. When enough information is known to identify characteristics that may influence the phenomenon, a Stratified Purposive sample makes it easy, fast, and systematic to get a representative sample [4]. For a homogenous study population and focus research aims, sample size recommendation varies widely, 5-60 recommended by Guest et.al [32], Constantinou et.al [33], Hagaman and Wutich [34] and 2-40 focus groups [35]. Also small sample sizes are effectual for qualitative research, and the effective sample size is less about numbers and more about the potential of data to produce rich and nuanced accounts of the phenomenon researched [36].The method helps to identify and expand different characteristics and focus on their interrelationship. Moreover, this also helps select from an information-rich area considering the participant's interest, availability, and willingness to give unbiased responses [22].

First, we identified all possible external and internal characteristics that can influence the reconstructed buildings, and then, we created their groups and subgroups. Then, a sample was taken from every subgroup as a representative sample for our study data set. Understandably, for every sample, there were overlapping in the groups, thus providing a richer data set for the evaluation.

Rapid Visual Screening

Bhalche Ward No 1

Photograph	**Owner's Name:** **Address** **Other ID:** **Use :** **Screener(s)** **Date/Time:**
	No of Stories : **No of Rooms:** **Year Built:** **Total Floor Area (sq ft) :** **Additions:** **Occupancy :** *Residental*
	Socio -Economic Aspect
	Ethinicity : **Education Level :** **Income Source:** **Monthly Income :** **No of Residents**
Sketch	**Comments:**
	Geological Aspect:
	Soil Type : ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☐D Stiff Soil ☐E Soft Soil ☐F Poor Soil
	Geological Hazards : *Liquifaction:* / *Landslide:* / *Surface Rupture:*
	Adjacency
	Irregularity

Beneficier :	**(Full / Partial / Non)**	**Toilet:**		**Comments:**
Built Accoring to the Catalogue :	☐ **Yes** ☐ **No**	**Biogas :**		
Model No :		**Solar Power:**		

Site Selection		**Opening**	
Geological Fault or Rupture		Opening Distance form Corners >600mm	
Area Suspectible to Landslide		Span of Opening > Half of Wall Length	
Steep Slope >20%		Horizontal Spacing Between Windows>600mm	
Filled Area		Lintel Level on Door and Windows	
River Band and Water- Logged area			
		Vertical Reinforcement	
Shape Of House		Reinforcement Diameter	
No of Storey			
Span of wall >4.5m		**Horizontal Reinforcement**	
Size of Room >13.5 sq.m		Sill Bands	
Height of wall >3.0		Sill Bands > 75mm	
Proportion of Building (l/b>3)		Lintel Bands	
		Lintel Bands > 150mm	
Foundation (Inquiry, if possible)		Roof Band	
Depth for Single >0.8m		Roof Band >75mm	
Depth for two Storey >0.9m		Reinforcement	
Approximate Depth of Footing			
		Roof	
Plinth		Wooden or Steel Truss	
Plinth Level Above from G.L>300mm		Proper Truss Joints	
Height of Plinth >150mm		Cross Tie	
Width of Beam >350mm or Wall Thickness		Timber Condition	
Reinforcement Used in Plinth			
		Materials	
Wall		Building Material:	
Masonary type :		Material Condition :	
Width of Wall >350mm		Reinforcement	
Staggered Masonry:		Concrete Ratio:	

Extend of Review		**Other Hazard**	**Action Required**
Exterior	☐Partial ☐All Sides ☐Aerial	Are there Hazard that Trigger a Detail Evaluation ?	Detailed Evaluation Required ? Yes /No Reason :
Interioir	☐None ☐Visible ☐Entered		
Drawing Reviewed	☐Yes ☐No	Geological Hazard or Soil Type F ?	
Soil Type Source :			
GeoHazard Source:		Significant Damage in Structural Element?	
Interviewed Name :			
Contact No :			
Level 2: Further Screening Performed ?	☐ Yes ☐ No	Significant Damage in Non-Structural Element ?	
Non-Structural Hazard?:	☐ Yes ☐ No		

Figure 2: RVS format used in the survey

Key Informant Interview

Name:	
Address:	
Beneficiaries Classification	
House Type (Before earthquake) :	
House Type (After earthquake):	
Total Tranche Received :	
Total Cost in Construction :	
Transfer of Knowledge	
NRA Involvement and Inspection	
Pre Construction :	
During Construction :	
Post Construction :	
Recommendation:	
Other Remarks:	

Interviewer:

Figure 3: KIS format used in the survey

3. Study Area

Nuwakot district was one of the 14 crisis-hit districts during the 2015 Gorkha earthquake. Most of the district's area is underdeveloped and covered with challenging terrain ranging from 457 to 5144 m from mean sea level[5] Bhalche, Ward 1 in Kispang Rural Municipality located in Nuwakot (Figure 4), was also severely affected. Before the earthquake, 97.5% of buildings in Bhalche were non-engineered stone masonry in mud mortar, with galvanized iron sheet roofs [18].After the earthquake, most buildings in Bhalche became inhabitable because of the age, material, design, and site of the building. Post-disaster government's initial damage evaluation for structure's performance level and hazard association using damage level from Grade 1 to 5: 1 refers to insignificant damage and 5 for extreme damage with structural replacement [1]defined 95% of buildings in Bhalche as Grade 4 and Grade 5. Nevertheless, within the reconstructed buildings, more than 87% are masonry buildings. Considering the prior weak performance of masonry houses and the present day's large number of reconstructed masonry buildings, Bhalche is a suitable study area for our research. Bhalche, with a 29.57 sqkm area, is an economically and educationally backward region predominantly inhabited by the indigenous Tamang community. 21.6% of people in this area are uneducated, and 69% of households have an average monthly income of less than NRs 10,000 [18].In the post-disaster assessment in Bhalche, 1175 houses were eligible for government support. But the recent data showed that only 91% of them had received the final installment of the grant.

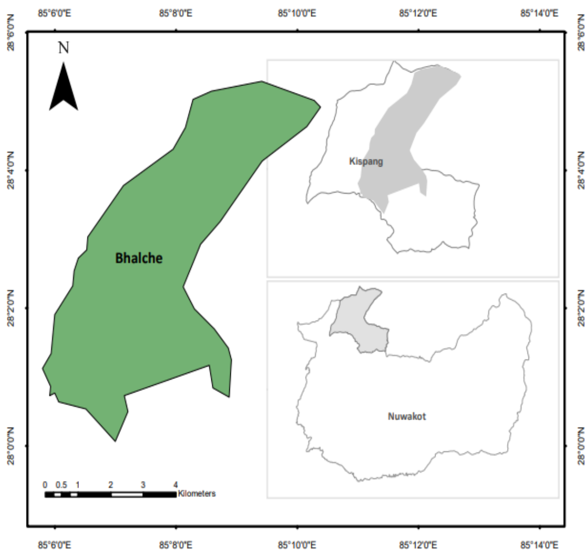

Figure 4: Study Area: Bhalche, Nuwakot

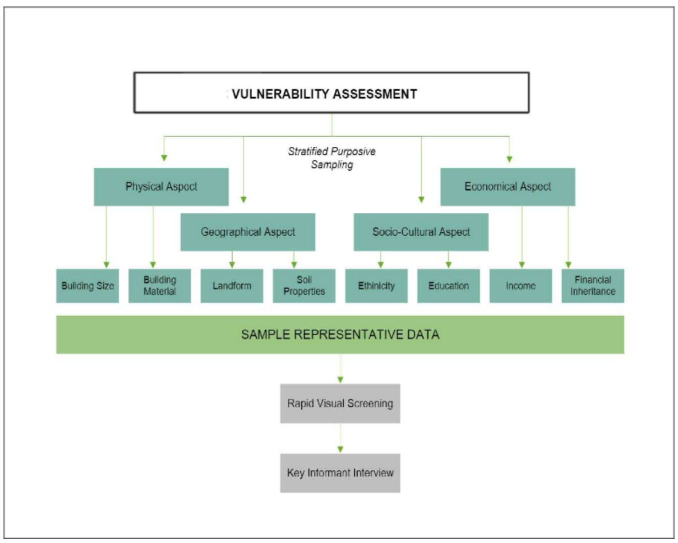

Figure 5: Stratified Sampling Framework for Sample Selection

Considering these circumstances, four different groups were identified in Bhalche that can influence the reconstruction. As shown in Figure 5, the Physical Aspect, Geographical Aspect, Socio-Cultural Aspects, and Economical Aspects. These groups were further divided into corresponding subgroups. These definite and distinct subgroups were then used to identify and select houses to make a comprehensive and representative sample set. Considering all the subgroups, atotal sample set of 50 houseswere selected for multi-modal evaluation.

4. Findings of the Case Study

4.1 Building Typology

Before the Gorkha earthquake 2015, masonry buildings were the most prevalent building type, and they suffered severe levels of damage. Although the post-earthquake reconstruction survey shows a similar trend in construction, better seismic resilience is expected for these reconstructed buildings. Post-disaster statistics show that out of 1175 reconstructed buildings more than 48% of the reconstructed buildings in Bhalche are brick masonry in cement mortar, 37% are stone masonry in mud mortar, 2 % are stone in cement mortar, and the remaining 13% are reinforced cement concrete (NDLPIU, 2021). This section provided further information on the masonry building typologies present in the study area. Wood and GI pipes are used for the trusses and CGI sheets are for the roofing.Most of the structures constructed are one-room buildings. Even though most of this one-room building has a carpet area larger than 11.137 m^2, ascribed as the minimum carpet area by NRA, the utility aspect of the space is largely compromised. Many of these structures were found to be used more as storage rooms for crops, cattle, and animal dung as in Figure 9. A few multi-roomed and two-storied masonry structures can also be found in Bhalche.

4.2 Evaluation of Reconstructed Building

During the inspection, some blatant issues were found in most of the buildings. In this section, we discuss the significant discrepancy between the provided design and construction in Bhalche. Also, we further attempt to understand the reason behind negligence in reconstruction from the beneficiary's perspective.

4.2.1 Noncompliance Issues in Reconstructed Building

The majority of the reconstructed building in Bhalche have minor to medium-range non-compliance issues compared with the minimum requirement for residential masonry buildings as stated by NRA. Some of the major inconsistencies in construction were:

i. **Site Selection**: 5 % of the reconstructed buildings were constructed on steep slopes with underlying soft soil deposits along with decayed rocks, so the areais highly susceptible to landslides (Figure 6) during rainy seasons. It was found that an alternate land was provided to those fifteen house owners residing at that unsafe site forreconstruction, however, three of the house owners have not left the place yet due to poor economic backgrounds and unavailability of land and employment in alternate places for agricultural purposes.

ii. **Size of the room**: 95 % of buildings are one-room structures: Although these houses met the minimum carpet requirement stated by NRA, the 'functional'aspect is compromised. Most people have constructed an additional CGI shed on the side to accommodate the need for space.

iii. **Masonry Wall**: Vertical joints in the masonry wall (brick) are prominent in some buildings (Figure 11).

iv. **Roof truss detailing**: In some of the buildings/houses (15%) Kingpost, Rafter and Purlin are deficient in numbers as shown in Figure 12 than in the drawing provided by NRA which may be the possible point for vulnerability resultingin a significant consequence by the hazard-likestrong wind storm.

v. **Horizontal band for integrity***:* Use of intermediate bands –all of the houses constructed before the Grant andtechnical assistance from the Government of Nepal (GON), sill and lintel bands were placed in a haphazard manner (Figure 8) although, houses built with the grantand technical assistance from the GON has used in proper ways as in design catalog/Drawing (Figure 10) except a very few houses(3 out of 50) does not have bands as shown in Figure7and poor workmanship like the appearance of honeycombed in RCC band and lack of uniform thickness in wooden bands.

Figure 6: Vulnerable Area

Figure 7: House with No horizontal band

Figure 8: House with the haphazard location of bands

Figure 9: House being used for storing cattle

Figure 10: Houses build following NRA technical guideline

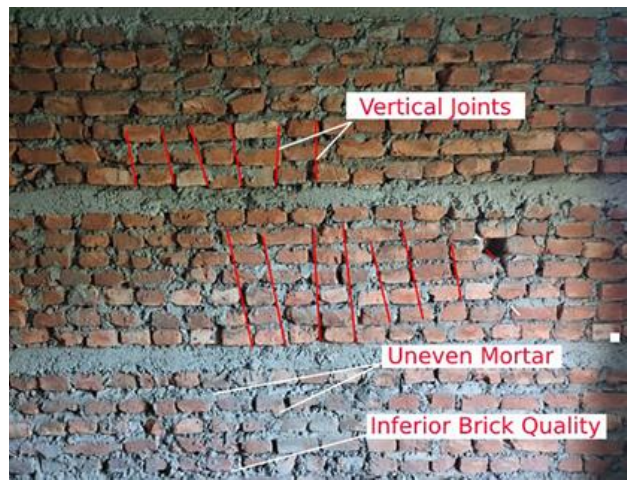

Figure 11: Vertical joint in brickwork

Figure 12: Inadequate rafter and Purlin in roof truss

4.3 Reconstruction Prior and Post-Financial Aid and Assistance

Two types of reconstruction were found: one group that started the construction before any government assistance, and the others that started after receiving the assistance. These groups can be easily distinguished from their preferred construction, where the latter has a better resemblance to the NRA's model designs. In Bhalche, after 97% of the residential building suffered inhabitable damage from the earthquake [NPC, 2015], people with decent backgrounds immediately started the reconstruction before any governmental aid. Among these people, few independently sought technical assistance to build better houses, whereas others with their immediate need for residence completely neglected the importance of constructing houses with better resilience. Likewise, among others who started the construction after the government assistance, many had a vague understanding of the scope of the provided aid. Due to this lack of information among the beneficiaries, many misunderstood the provided aid as the amount for the entire construction cost and built a small single-room structure. In addition, the inclusion of a one-roomed building in the Design Catalogue: Volume I have encouraged this type of practice. From the KIS, other aspects that influenced reconstruction are provided as follows.

4.3.1 Psychological Dimension

In rural areas like Bhalche, superstition and myths are still entrenched in people's lives, primarily prevalent in the uneducated and elderly. Some people still believe that any mishappening and disaster are an outcome of God's rage toward their people and community, consequently believing an individual's fate and destiny as the chief motive and purpose for living. This superstition and cultural belief have induced backwardness in many people and resulted in reluctance toward disaster preparedness and management. Due to this lack of knowledge and ignorance, many victims were hesitant and overlooked the significance of investing in a seismic resilient structure.

4.3.2 Geographical Dimension

Bhalche is a secluded area where proper transportation infrastructure isn't available, with most places joined by rural earthenroads. The conveyance of the raw material and skilled workforce to this area is challenging and equally expensive,as the transportation facility is accessible for up to 6/7 months during summer and winter, resulting in high construction costs. Considering the people's preceding financial condition and the weak monetary support provided by the government, building a resilient and better house was difficult.

4.3.3 Economical Dimension

More than 92% of people living in Bhalche have a monthly income of less than NRs 20,000.00, and most of them depend on daily labor wages [25]. During the earthquake, these people's employment was majorly interrupted, creating difficulties in fulfilling their basic needs. Due to their destitute condition, these people relied on debt and loans during this period. With the delay in access to the grants, significant debt accumulated and accrued, and many people used these grants to repay the incurred debt. Eventually, people had a small sum remaining to construct a house.

4.3.4 Personal Motive Dimension

While understanding the dynamic nature of disaster in people's psychology, individual benefit played a significant role in manipulating reconstruction and grant distribution. Key Informant Interviews helped the researchers to understand that many people had used the relief as an opportunity for personal gain. Many people were initially facing difficulties accessing financial grants; on the contrary, other privileged people were concocting plans to get compensation for the building that were inhabitable before the earthquake. Reconstruction for many buildings was solely performed to receive financial aid, resulting in a lack of attention toward quality. Out of surveyed houses, fifteen houses were built only for monetary incentives and are now left without living as beneficiaries used to live in nearby cities.

4.3.5 Knowledge Gap Dimension

In the initial part of the disaster response, NRA was mainly focused on the financial aspect and was less attentive to the technical aspect. NRA took almost one year to deploy engineers in the field. By this time, many people had already built their houses per their preference. Likewise, technical jargon impeded an effective transfer of knowledge between the engineer and beneficiaries even after the assistance.

4.3.6 Financial Dimension

During these challenging times, people in Bhalche did not have access to a low-interest loan scheme, seemingly due to the reluctance of private banks to provide an affordable mortgage. Provided that financial aid was far from the total construction cost, 90% of the people were left to manage the required money by themselves. While few people fell into debt traps, many decided to avoid the loan scheme and completed the construction within the provided financial aid by deliberately avoiding many construction details.

4.3.7 Case Study example of KIS

A particular case from the pool of 50 case studies (out of these 50, 13 beneficiaries each have two houses-one, constructed by themselves without technical and financial backing from GON and other NRA-assisted)is presented in this section. The data and information presented in this case study were derived from the RVS and KIS. This shows the scenario for low-income households in Bhalche during the reconstruction.

Maru Rani Tamang is a 65-year-old woman currently living in Bhalche, Kispang. She lives with a family of 5 members, with an overall monthly income of NRs 20,000. She is the interviewee for this particular case study. During the Gorkha earthquake, their three-storied building- made with stone masonry in mud mortar- collapsed (Figure 13). Consequently, her family lived in a temporary shed after the catastrophic event. Even after seven months after the event, due to the absence of aid from the government, they collected NRs 7, 00,000 from their relatives to construct a two-storied mud-mortar stone masonry building (Figure 14). Since they had started before the technical involvement, the house was made according to traditional practices. After the grant was announced, Maru and her family were thrilled and expected to receive them. But the funds were for technical and financial incentives for seismic resilient houses, the constructed building required the NRA engineer's approval. Since the house was made without any technical assistance, the house couldn’t get approved. They were recommended to build a new house as per the NRA requirement to receive grants. For the sole purpose of getting the grants, a new house was built with the NRA's assistance as shown in Figure 15. But since they had already spent considerable money on their house, the new house was constructed as a single-room building. Due to the limited space in the home, incapable of accommodating the family, the family still preferred their previous non-compliant house for living. The new house is used for storage. During the investigation, we found that old house doesn't affirm many requirements such as:

- No sill and lintel bands on the first floor.
- No intermediate, gable, or roof band provided.
- The placement of the window is random, without any consideration to the bands provided, etc.

Figure 13: House destroyed By Gorkha earthquake

Figure 14: House build without technical assistance

Figure 15: New house after grant and technical assistancefrom GON, NRA.

5. Discussions

Non-compliance issues in post Gorkha earthquake masonry buildings in Bhalche, Nuwakot were due to the economic hardship, deficiencyof adequate technical information and assistance,monetary interest of a people, and taking into account reconstructed houses as a short-term solution with no future planning for functional requirement, etc.Similar issues werefound in Sindhupalchowk district as well [2]. In most cases, financial constrain were the primary reason behind people's reluctance to adhere to therequirements like the utility aspect.However, considering the inexpensive nature of masonry buildings,where locally available materials were prioritized, NRA could have handled this problem.According to the beneficiaries, NRA lagged in immediate response after the earthquake. Many people started the construction immediately due to their need for accommodation whichresulted in skipping technical assistance. Likewise, even after the technical people’s involvement, aninadequacy in knowledge transfer was found. People criticized that, even though NRAprovided seminars and meetings for awareness, due to the involved technical jargontheygot confused and eventually made their own construction choices. Moreover, due to the significant lack of skilled masons and financial allowances, manyownerstraditionally built their own houses.

Considering that the noncompliances are mild, different easy and inexpensive approaches are available for resilience augmentation, primarily from NRA's correction and exception manual. Due to similar issues found in reconstruction in many places, NRA has published this manual, providing several step-by-step correction measures. These corrections are simple and cheap using locally available material. Additionally, a recent study on non-compliant reconstructed masonry buildings found that the minimum requirement from NRA seeks higher demand than codal provision, so the overall outlook on vulnerability can be expected to be on the safer side. Nevertheless, rectification should be mandatory, as better resilience can mitigate the damage in future earthquakes.

6. Conclusions

The qualitative study of residential masonry building constructed after the Gorkha earthquake 2015, was carried out using KIS and RVS with an extensive field visit in the Bhalche, a rural ward in the Nuwakot district of Nepal where means of transportation is entirely blocked for up to 5 months due to different circumstances such as rainfall-induced landslide, flood and other various reason. Majority (90%) of the reconstructed houses with the backing of GON/NRA do not meet the utility requirement of rural life, and have minor non-compliance issues, although houses constructed before the technical and financial grant from the GON are present in significant numbers, that are traditional, non–engineered and does not satisfy the minimum provision stated by NRA. Also, people are residing in these traditional non-engineered houses, as NRA-assisted one-roomed house do not meet their needs, becoming more vulnerable to future earthquakes. Some of the conclusions drawn from the results obtained from the study are presented:

1. There are notable minor non-compliance issues in the reconstructed residential masonry building such as site selection, workmanship, laying of joints of brick absence and uniformity of thickness of the horizontal band, inadequate rafter-purlin in roof etc., which requires more thorough seismic analysis.
2. Out of 50 samples of case studies, 13 beneficiaries had reconstructed two houses, one after getting technical and financial support from the GON and another before NRA's initiatives for reconstruction, which was non-engineered and all of these thirteen houses do not fulfil any requirement set by NRA.
3. As the study finds a remarkable number of traditionally reconstructed residential masonry houses, which do not deploy any NRA minimum requirement, so more focus should be on these areas to mitigate the probable hazards and their consequences.

Overall, NRA had completed the reconstruction in the Bhalche, and what we have to do is prepare for the forthcoming disaster via further research works using a different perspective. The conclusion may not be valid for any other locations of an earthquake-affected district of Nepal, so further study is indeed by considering a wider scope, locality, area, field test, and detailed seismic evaluation.

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