Reconstruction Building Typology and Major Non-compliance Issues: Post-Earthquake Experience from Dhading

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Abstract

After the 2015 Gorkha earthquake, the Government of Nepal constituted National Reconstruction Authority and decided to provide grant to the house-owners who lost their house to construct code compliant and earthquake resistant buildings. But some of the reconstructed buildings could not meet the minimum requirements set up by the government failing to receive grants. Real scenario of reconstructed building typology is presented in order to discuss about the major noncompliance issues found in both RCC frame and load bearing structures. The study is evident that some new construction practice has evolved after the earthquake and some of building typologies are noncompliant which further need certain structural assessments to provide grants. The paper also intends to deliver efforts made by district supports engineers to solve those noncompliance issues. The issues are resolved primarily by structural analysis using software, or according literature reviews. Analysis shows only 15.2% of noncompliant buildings are structurally unsafe and could not be recommended for tranche. The research is based on the data received by district support engineers from field technicians, third party monitoring agents and partner organizations. Intensive field visits, formal and informal meetings, seminars are also being followed in this research. Since the paper is outcome of rigorous structural analysis of reconstructed buildings, this can be useful for structural engineers to provide the solution of different technical issues in residential buildings.

Keywords: Gorkha earthquake, Reconstruction, Building typology, Noncompliant, Tranche, District Support Engineer

1. Introduction

On 25th April 2015, massive earthquake of magnitude 7.8 M (USGS) struck Nepal with epicenter in Gorkha with series of aftershocks. The disaster caused huge loss of life and property as well as physical infrastructures. The Post Disaster Needs Assessment (PDNA) identified 31 districts as earthquake affected districts, among which, 14 districts were categorized as most affected districts and 17 districts as least affected districts. Dhading is one of the most affected districts. Government of Nepal (GON) classified the earthquake victims into two categories i.e. Reconstruction beneficiary and Retrofitting beneficiary. Reconstruction beneficiary would receive Rs. 3,00,000 grants and retrofitting beneficiary would receive Rs. 1,00,000 grants. Both reconstruction beneficiaries and retrofitting beneficiaries are set to get first tranche (Rs.50,000) after agreement signing. In the case of reconstruction beneficiaries, second tranche (Rs.1,50,000) is provided after construction up to plinth level and third tranche (Rs. 1,00,000) after construction up to roof band level. Retrofitting beneficiaries, however, are set to get remaining amount (Rs. 50,000) in second tranche after completion of retrofitting.

The government constituted National Reconstruction Authority (NRA) after nearly eight months of devastating earthquake and it took almost one year for the deployment of engineers and to reach field level. By this time, many people had already rebuilt or repaired their damaged houses in seek

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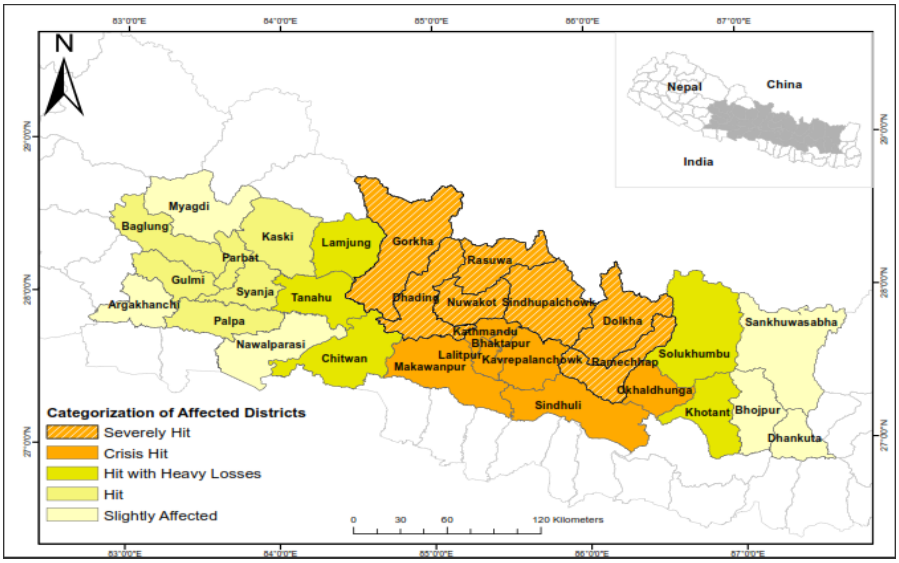

Figure 1. Categories of earthquake affected districts (Source: PDNA 2015 report)

of a proper and safe shelter. Those beneficiaries were unknown regarding the newly formulated norms of reconstruction and grant distribution policy of NRA. On the other hand, the beneficiaries who didn't immediately reconstruct their houses were also initially reluctant to build earthquake resistant houses as prescribed in the NRA guidelines by presuming its construction difficulty and high cost. In order to support the reconstruction, the government also published different design catalogues and checklists for the aid of beneficiaries. But these designs catalogues also could not address the actual need and intention of the people. So, beneficiaries started to construct their building in their own way. As a result, buildings were found noncompliant (NC) to provide grant and this created a big problem. The problem got even bigger when field technicians were also in confusion regarding norms of NRA even when the beneficiaries intended to follow the guidelines. So, to resolve solution to all the above-mentioned problems, NRA recruited 27 district support engineers (DSE) on 15 May, 2017 in 14 most affected districts who are technically sound. The main purpose of hiring DSE is to support field level technicians on technical issues and solve noncompliance issues. After the presence of DSE in the district, most of noncompliance issues could be solved at district level but some unsolved issues were forwarded at central level to find the better solutions.

2. Methods of Data Collection

The research is carried out on the basis of data received by district support engineers working in Dhading. Field technicians are the primary source of data collection. They fill up different inspection sheets, assigned formats and provide photos. The data provided by field technicians are analyzed and reviewed by DSE. Further, regular joint field visits conducted by DSE with focal engineers, monitoring and evaluation expert, Housing Recovery and Reconstruction Platform (HRRP) is another source of data collection during which direct interviews are conducted with beneficiaries, field technicians and local bodies. Some data are also made available to DSE by partner organizations (POs) and third-party monitoring agents (TPMA) through their field visits. Different formal and informal programs attended by DSE at district level and local levels is other way to collect data.

3. Building Typology

Dhading district consists of total 13 local bodies, two urban municipalities and eleven rural municipalities. Mostly, load bearing structures are found in rural areas and frame structures in urban areas but changes are noticed in building types after the earthquake. Load bearing structures are replaced by RCC structures even in rural areas with the common perception that any type of RCC structures are more earthquake resistant than load bearing masonry structures. Also, due to poor mobilization of technical persons in field resulting the lack of socio-technical awareness that masonry buildings also perform well during earthquake, further helped this process. Building typologies presented in this research are not only based on construction materials but also based on construction practice.

3.1 Based on construction Practice

i) Corner Column: In this type of buildings, columns are casted at corners and wall intersections to replace the corner stones of masonry buildings. Size of columns can be variable with sizes 9”x9”, 9”x12”, 12”x12” with different rebar specifications. These buildings neither meet the criteria of fully load bearing structures nor confined masonry structures. Building with RCC columns and flexible roofing can also be categorized in this type of structure. Generally, RCC column with flexible roofing results when houseowner initially starts to construct RCC building but later installs flexible roofing due to financial problem. The best suggestion for the houseowner from structural point of view is to construct fully confined masonry.

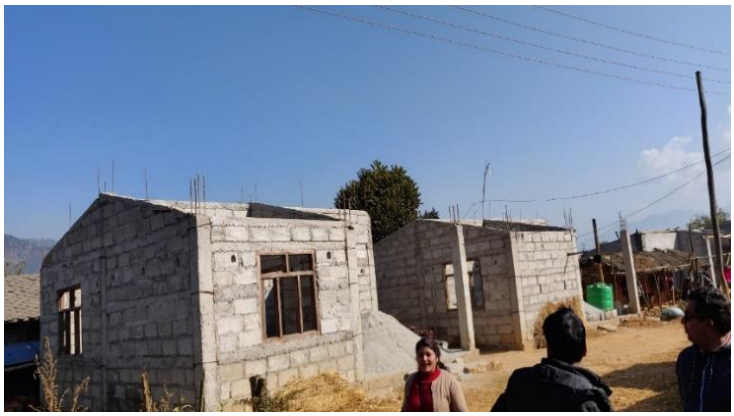

Figure 2. Corner column structure with hollow concrete block

i) Single room: Based on data received in the district office, nearly 35% of newly constructed building are single room. The main reason behind this is community members perceived grant not as assistance rather as compensation provided to cover the reconstruction cost of their damaged house. Including single room building in one of the 17 designs in volume catalogue I and tight deadline for grant disbursement provided by NRA at different times further aided to construct this type of buildings. Later, NRA published minimum requirements for single room house but it was too late for the announcement. Some beneficiary also constructed single room house just to receive tranche as their previously reconstructed building was noncompliant.

ii) Hybrid structure: There are two type of hybrid structures, combination of load resisting system (RCC at ground floor and masonry with flexible roofing at first floor) and combination of materials (load bearing walls at ground floor and timber or steel frame with CGI covering at first floor). Second one is found more prevalent in different parts of Dhading. After the Gorkha earthquake, people realized that load must be reduced in upper floor to lower the damage during earthquake. Hybrid structure is the outcome of the realization. NRA has published Hybrid structure manual to support field level staffs for inspection of those houses.

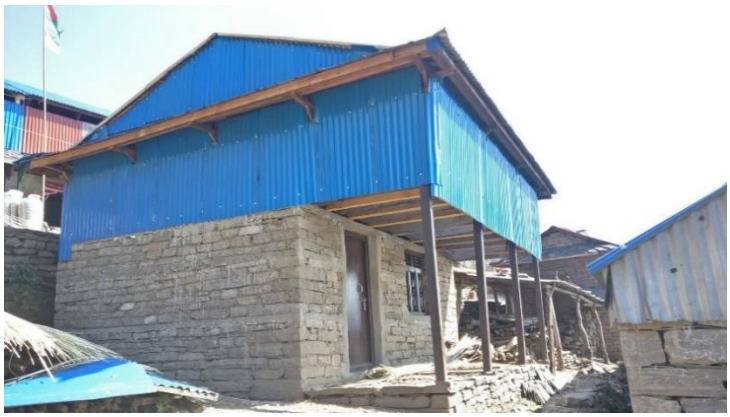

Figure 3. Hybrid structure with CGI covering at first floor

3.2 Based on construction material:

i) Dry stone masonry: These types of houses are found especially in Northern part of Dhading, Ruby Valley Rural Municipality, where strength of mud mortar is low for construction of mud mortar stone masonry. Also, in these regions, high chances of mud mortar getting damaged by rats provides additional demerit for mud mortar stone masonry. Most of the dry-stone masonry houses are single room where timber is used as horizontal bands and vertical posts.

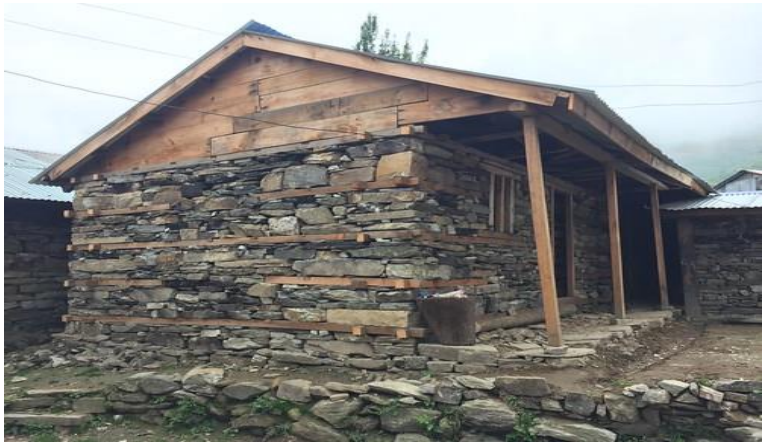

Figure 4. Dry stone masonry

ii) Concrete blocks: Blocks production factories evolved just after earthquake in the areas near to highway where cement is readily available. These blocks can be hollow concrete blocks, solid blocks, compressed stabilized earthen blocks, interlocking blocks etc. Size of blocks may also vary. Buildings made with these

blocks and cement mortar falls in this category. Most of the locally made blocks do not meet the requirements prescribed in design volume catalogue II.

Figure 5. Load bearing interlocking block with cement mortar

iii) Stone masonry: These are the most common type of buildings found in rural areas of Dhading. Stones are either bonded with cement or mud mortar. Walls are normally 14 inches or 18 inches thick and constructed in multiple wythes. Height of building can be one storey or two storey depending on wall thickness, type mortar used and type of horizontal band. Flooring is normally timber joist or bamboo with mud plaster and roof is generally constructed with rafters and CGI or tiles covering.

iv) Brick masonry: These types of buildings are also found in rural areas of the district. Bricks are either bonded with cement or mud mortar. Walls are normally 9 inches thick and flooring is normally timber joist or bamboo with mud plaster or RCC slab and roof is generally constructed with rafters and CGI or tiles covering.

v) RCC framed structures: These buildings are constructed by cast in situ concrete columns, beams and slabs. They have brick walls or block walls as infill walls and can be pre-engineered or engineered. RCC structures are mostly found in urban areas with higher number of storey than other type of structures. Trend of construction of RCC structures in rural areas has begun after the Gorkha earthquake.

4. Non-Compliant Structures

The main objective of establishment of NRA is to build a multi hazard resilient community providing socio-technical assistance and grants. Beneficiaries receive grants if their building are earthquake resistant or code compliant. A structure is categorized as noncompliant if it does not comply with minimum requirements (MRs) set up by NRA. The minimum requirements are provided in the form of different inspection sheets. At first, field technicians check compliance of building as per inspection sheets. Then they report noncompliant buildings to DSE for structural analysis. The noncompliant buildings do not always mean they are structurally unsafe and unable to receive grants. However, these buildings can be recommended for tranche if they are found safe according to building codes (NBC 105, IS 1893) otherwise DSE provide some correction methods to make building code compliant and tranche can be released after application of process.

Beneficiaries even after getting all the tranches, did additional construction activities in the houses in their own way. Most of beneficiaries added storey more than prescribed in MRs and did some modification in their houses. All of these additional construction activities also made their buildings noncompliant. It would have been better if system of releasing third tranche was set to provide after the completion of house rather than after construction of roof band level. This would have prevented beneficiaries to do additional construction in their own way after getting final tranche. The major noncompliance issues found in Dhading are listed below:

RCC framed structure:

- Column size <12"x12"
- Reinforcement in column < 8 nos. (4-16Ø+4-12Ø)
- Plan and elevation irregularities
- Panel area > 13.5 sq. m.
- Column spacing <2.1m &>4.5 m
- One bay building
- Aspect Ratio >3

Load Bearing Structure:

- Absence/ discontinuity of horizontal bands
- Absence of vertical reinforcement
- Absence of roof/gable band

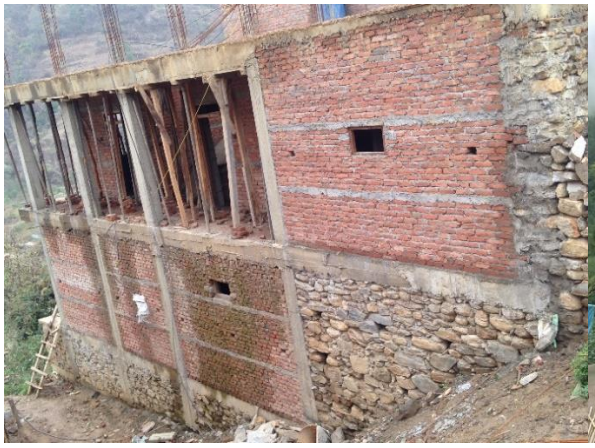

Figure 6. RCC building with 9x9 column

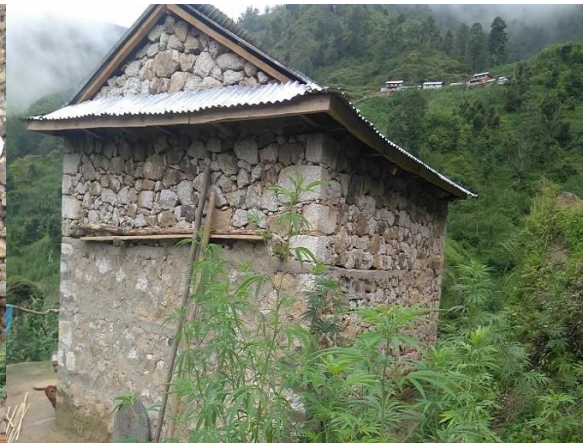

Figure 7. Stone masonry building with no gable wall

Scenario of noncompliant buildings: The table below shows the actual scenario of the noncompliant buildings at different local levels of the district at the end of March 2020. Nilkantha municipality has highest number of noncompliant buildings while Tripurasundari-6 has the least. Noncompliance cases in RCC buildings are found to be higher than in masonry buildings. The reason behind large number of noncompliance cases for RCC buildings is due to lack of trained mason for construction of RCC building in rural areas and field technicians submitted mostly RCC buildings to DSE for structural analysis. They tried to provide solution of noncompliant masonry buildings as per E/C manual themselves. Out of the total noncompliant buildings reported to DSE, only 15.2% are structurally unsafe and could not be recommended for the tranche. Based on TPMA report, 4.5% of the total reconstructed buildings in the district are noncompliant which is quite satisfactory result of rural housing reconstruction.

Table 1. Status of noncompliant buildings in Dhading

National Reconstruction Authority(NRA)										
Dhading District										
Date:	March, 2020									
S.No.	Name of RM/UM	Type of Building								Remarks
		RCC		BMC		SMM/SMC		Others		
		Safe	Solution Required	Safe	Solution required	Safe	Solution required	Safe	Solution required	
1	Benighat Rorang RM	6	2					7		
		16	0					8	0	
		1	0							
		1	0							
2	Dhunibesi UM	49	3							
		19	6					1	1	
		155	16	13	14	2	21	4		
3	Gajuri RM	176	7					2		
		53	7					29		
4	Galchhi RM	66	2				2	23	2	
		19	0							
		20	3					12		
5	Gangajamuna RM	15	2							
		14	0							
						15				
6	Jwalamukhi RM	15	8				1			
		11	1							
		11	1							
		50	1	3		4	3			
7	Khaniyabas RM	12	0							
						2				
8	Netrawati RM	18	0	3		2				
		4	0							
								3		
9	Nilkantha UM	274	46	3	5	2	6	44	5	
10	Siddalekh RM	160	20		1	1	20	6	9	
		26	3			29	3	7	0	
		43	13							
11	Thakre RM	57	22						14	
		4	4							
		110	34					43	8	
12	Tripursundari RM	1	0							
		0	1							
		20	2							
		103	3							
		2	1					2		
	Total	1531	208	22	20	57	56	191	39	

5. Recommendations from DSE

As earlier said, DSE check compliance of structures, recommend corrective measures to noncompliant buildings and provide technical suggestions to the beneficiaries. The check of building is done primarily by structural analysis using software like SAP 2000, ETABS or according to exception and correction manual (E/C manual). The recommendations presented in this section are based on structural analysis, literature reviews of various noncompliance issues observed in Dhading. Some of the efforts made by DSE to solve typical noncompliance issues are:

S.N.	Major noncompliance issues	Explanation	Solution
1.	RCC frame structure with 10mm rebar in vertical member(column).	As per IS 456, it is not allowed to use reinforcement less than 12 mm in compression member.	The structure is as analyzed framed structure with infill walls not as bare frame structure.
2.	Lack of horizontal bands and vertical reinforcement in load bearing structure.	Horizontal bands and vertical reinforcement are required to take lateral load.	Correction is provided as per exception and correction manual and structural analysis.
3.	Corner columns instead of single vertical rebar and Building with RCC columns and flexible roofing.	Columns used at different locations of the wall only replace corner stones but do not take gravity loads and act as frame system unless it is connected by beams/slabs.	At first, structural analysis is carried as a load bearing structure and effect of columns is not taken into consideration. Later, rebar required to take tensile stress is compared against the rebars in columns.
4.	Steel pipes used at different locations of walls instead of vertical reinforcement.	Circular/square steel pipes used at different location of walls do not act as truss unless it is moment resisting frame.	Fundamentally, these structures are load bearing types. Equivalent size of TMT steel is calculated from steel section taking stress into consideration.
5.	Absence of roof /gable band.	The gap between the top horizontal band and rafter/purlin is filled with two or three layers of masonry units with mortar.	The masonry above band has very small height. It is also restrained by vertical elements on sides so failure is unlikely to happen in this zone (Exception)
6.	Discontinue horizontal/roof band	Discontinuity of horizontal band is mainly due to presence of NIDAL at floor level.	Place NIDAL after casting roof band or correction of band connecting the discontinued bands.

6. Conclusions

This paper in general presents experiences gained during the rural housing reconstruction and non-compliance issues and their resolution. Following are the conclusions of this research.

- Some unusual type of buildings typologies like corner column, hybrid structures are seen after the Gorkha earthquake in different parts of district. Dry stone masonry and stone masonry structures are mostly found in northern rural areas whereas RCC framed structures and block masonry are mostly seen in southern urban areas.
- Beneficiaries didn't perceive grant as assistance but rather as compensation provided to cover the reconstruction cost of their damaged house. This resulted the higher number of single room buildings.
- The noncompliant buildings do not always mean they are structurally unsafe and unable to receive grants. These buildings can be recommended for tranche if they are found safe according to building codes (NBC 105, IS 1893) otherwise DSE provide some correction methods to make buildings code compliant and tranche can be released after application of process. Only 15.2% of the buildings are found unsafe from structural point of view failing to receive tranche.
- According to TPMA report, noncompliance issues of Dhading are quite less than other districts. Only 4.5% of the total reconstructed buildings in the district are noncompliant which is quite satisfactory result of rural housing reconstruction.

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