A Study of the Compliance of Residential Buildings with Design Standards and MRT Norms in Ghorahi Sub- Metropolitan City

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Abstract

Urbanization is accelerating globally, Ghorahi sub-metropolitan city is one of the rising urbanization cities in Dang district of Lumbini Province. Urban expansion in the region is largely driven by informal construction practices, with more than 70% of houses failing to meet building code requirements, which heightens their susceptibility to disasters such as the 2023 Jajarkot & 2015 Gorkha earthquakes. This study assesses the level of building code compliance in designed residential RCC structures within Ghorahi sub-metropolitan city, considering both completed and ongoing construction. A qualitative research design was employed, integrating literature review, field measurement & inspections and questionnaire survey & KII to collect and interpret relevant data.

Out of 10 completed buildings, only 3 were fully consistent with the approved designs, while most showed variations in staircase dimensions, waist slab depth, and room sizes. For under-construction structures, compliance was high in the sizing of major structural components such as columns (100%), but there were notable gaps in other areas, including concrete mix proportioning (only 5.4% compliance) and rebar lapping (54.54% compliant in columns and 13.6% non-compliant in beams). Although 84.37% of masons demonstrated good understanding of earthquake-related concepts, only 6.25% were aware of specific building code requirements. According to masons, the primary reason behind non-compliance was owner influence, accounting for 52.13%. Additionally, comparative study with Godawari, sisne & Birendranagar municipality has done and shown in table & charts.

Introduction

Nepal lies within one of the world's most seismically active regions and is recognized among the eleven countries most susceptible to earthquake hazards. Dang district is frequently identified as a high-risk seismic hotspot. The use of reinforced concrete (RC) construction began gaining momentum in the 1980s; however, scientifically engineered construction practices only started becoming widespread following the formal implementation of the Nepal National Building Code (NNBC) in 2006. Despite this progress, nearly 70% of RC buildings across the country continue to be owner-built, largely dependent on local contractors and guided by either municipal bylaws or the Mandatory Rules of Thumb (MRT) provisions under the NNBC [1]

Published by Graduate School of Science and Technology, Mid-West University, Nepal The NNBC categorizes construction practices into four distinct levels of sophistication: (i) International State-of-the-Art, (ii) Professionally Engineered Buildings, (iii) Mandatory Rules of Thumb, and (iv) Guidelines for Remote Rural Buildings [2]. Nonetheless, the dominance of informal construction remains a major concern, with over 80% of the housing sector operating outside formal regulatory mechanisms, where the implementation of building codes is minimal or absent. Even in formally approved projects, compliance enforcement is often inadequate, and building codes are frequently perceived as advisory rather than mandatory — a pattern also evident in other low-income nations [3].

Although municipalities are legally entrusted with enforcing building code compliance, their monitoring typically ends at the plinth inspection stage, focusing mainly on parameters such as plinth area, column size, and reinforcement diameter. More critical aspects, including concrete mix design, reinforcement detailing, anchorage length, and foundation depth, often remain unchecked due to limited field supervision and the absence of engineers or architects during the execution phase [4].

For instance, Ghorahi Sub-Metropolitan City mandates three stages of building approval and compliance verification: a temporary construction permit (up to plinth level), a permanent permit (post-plinth construction), and a final completion certificate. This study evaluates the extent of compliance with the NNBC and approved design drawings within, Ghorahi Sub-Metropolitan City, identifying prevailing gaps and recommending measures to promote safer and more earthquake-resilient construction practices. Similar concerns have been documented in Godawari's Integrated Urban Development Plan (IUDP), which underscores persistent challenges in project prioritization, regulatory enforcement, and the effective implementation of urban development initiatives [5].

Objectives:

A) a) To assess the level of compliance and non-compliance in designed residential building construction within GSMC.

B) b) To examine the awareness and practical experience of construction contractors and masons in adhering to building code requirements for residential structures in GSMC.

Literature Review:

Ghorahi Sub-Metropolitan City, situated in the Dang District of Lumbini Province, It was initially established as "Tribhuwan Nagar Panchayat" in 2035 B.S. and later expanded in Ghorahi sub-metropolitan city after federal system in 2072 B.S. with 19 wards, Ghorahi serving as Dang district headquarter.

Globally and within Nepal, numerous studies have underscored significant gaps in building code compliance and enforcement. For instance, research conducted in Cape Town revealed that limited awareness, lack of qualified professionals, and insufficient oversight were the primary causes of non-compliance, with only 3 out of 14 construction sites meeting the National Building Regulations

(NBR) requirements [6]. Similarly, in Karyabinayak Municipality, Nepal, design evaluations revealed deficiencies in ductility-related parameters such as stirrup spacing, bar anchorage, and reinforcement detailing, while around 15% of structures failed strength checks due to irregular building configurations and land plots [7].

Typical construction practices across Nepal demonstrate recurring weaknesses in reinforcement detailing, including the use of undersized longitudinal bars (12–16 mm diameter), inadequate stirrups (6 mm bars spaced over 150 mm apart), and rounded aggregates, all of which undermine the Mandatory Rules of Thumb (MRT) minimum strength criteria of 15 MPa. Additionally, reinforcement corrosion remains a persistent issue that further compromises durability and safety. In a survey conducted in Dang District, only 27% of respondents were familiar with the Nepal National Building Code (NNBC), and inspections were reported in just 33% of cases, primarily constrained by weak enforcement capacity and limited awareness of seismic risk [8].

Comparable issues have been identified in other South Asian contexts. In Bihar, India, for example, enforcement of building codes has been hindered by financial constraints, corruption, and institutional inefficiencies [9]. Within Nepal, studies from Nagarjun Municipality revealed that although MRT-based code implementation was introduced, its effectiveness was undermined by insufficient manpower, inadequate technical training, and lack of coordination among stakeholders [10]. Findings from post-2015 Gorkha Earthquake investigations confirmed that non-engineered buildings sustained the most severe damage, primarily due to poor construction materials and substandard workmanship [11].

However, there have also been encouraging examples of successful implementation. In Kakani Rural Municipality, approximately 74% of reconstructed buildings were found to be compliant with the NNBC, attributed largely to capacity-building programs and continuous supervision by engineers from the National Reconstruction Authority (NRA) [12]. Likewise, in Chandragiri Municipality, around 70% of reinforced concrete (RC) houses met code requirements, owing to the involvement of trained construction professionals [13]. In contrast, Sisne Rural Municipality exhibited extremely low compliance, with only 1 out of 27 completed buildings meeting the full NNBC standards. Frequent violations were observed in plinth dimensions, beam design, and staircase detailing, which were primarily linked to low technical awareness and unmonitored design alterations by owners [14].

A similar pattern of non-compliance was reported in Birendranagar Municipality, where most masons and contractors relied on experience rather than formal training to guide construction practices [15].Compliance evaluations in these studies generally focus on four major parameters: configuration (such as length-to-breadth ratio and cantilever size), strength (beam and column dimensions, slab thickness, and concrete grade), ductility (number and placement of bars, stirrup spacing, and anchorage detailing), and connections (lintel and sill bands, footing ties, and joint reinforcement). These parameters, as described in municipal case studies and national handbooks, provide a standard framework for evaluating code conformity [7].

On a broader scale, international research adds valuable perspectives on improving compliance.

Studies from the United States [16] and the United Kingdom [17] emphasize that training, enforcement consistency, and regulatory clarity play decisive roles in achieving higher levels of compliance. In the context of Nepal, emerging research from the Kathmandu Valley on green building practices has revealed moderate awareness among engineers and consultants, alongside inadequate policy mechanisms to support sustainable construction [18]. Comparative analyses of environmental protection clauses in national and international construction procurement frameworks further highlight disparities in safeguard standards, indicating a need for stronger environmental governance in Nepal [19]. In addition, delays in retrofitting public buildings, often caused by unrealistic project timelines and shortages of quality materials, continue to pose implementation challenges in earthquake-prone regions [20].

Research Design & Approach:

This research aims to study the construction compliance of residential building with design, reasons for not following the construction compliance, non- compliance parameter and best possible suggestions for the implementation of construction compliance in residential building at Ghorahi Sub-Metropolitan City, Dang District.

The study consists of qualitative research approach for analysis. The information was collected using Literature review, Field Survey and Collection of data, Questionnaire survey, KII, Data entry, analysis, and interpretation, Research report with findings and conclusion.

Study Area, Population, And Sample:

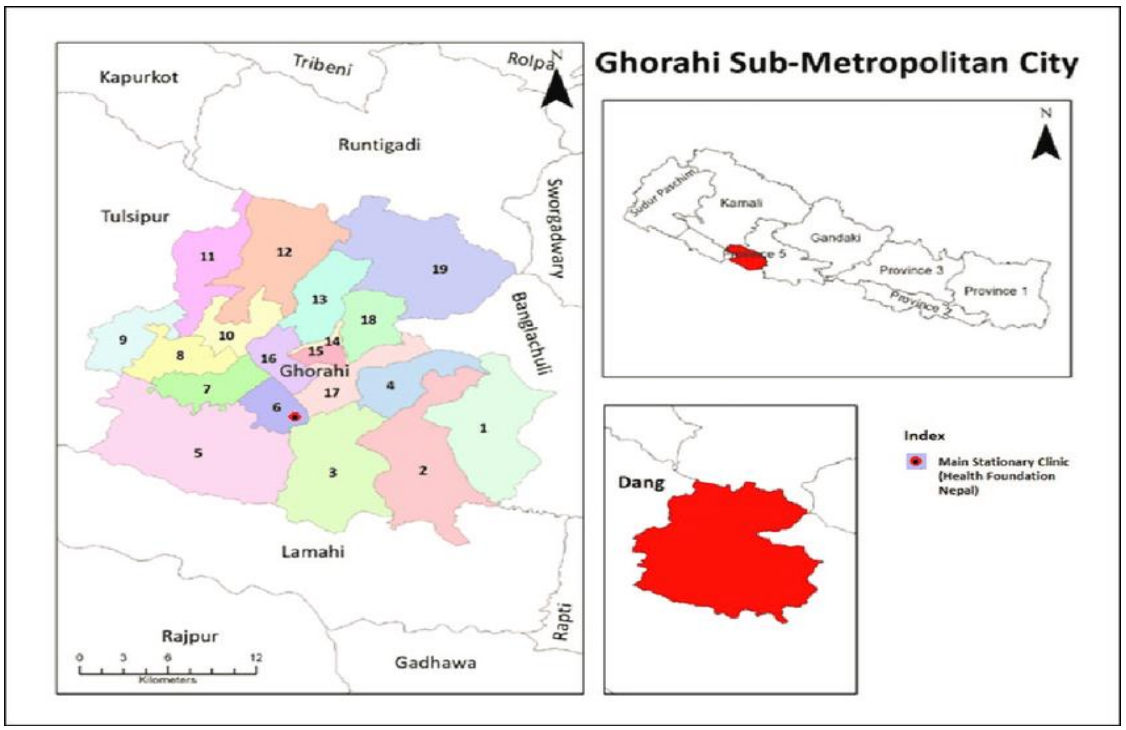


Fig 1: Geographical location of the study site.

The study area for this research comprises the residential buildings of Ghorahi Sub-Metropolitan City, located in the Dang District of Lumbini Province, Nepal. Ghorahi serves as the district headquarters and is recognized as the third-largest city in Lumbini Province. As of March 2022, the Ghorahi had a population of approximately 200,530, making it one of the fastest-growing urban centers in the country. Administratively, Ghorahi is divided into 19 wards, encompassing a mix of residential, commercial, and public structures at various stages of construction.

Study Population, Sample Size and Sample Polulation:

The study population was the registered residential building constructed after municipality make compulsory compliance of building laws i.e. onwards 2036/037 BS. As recorded in Ghorahi Sub-Metropolitan City office 2081/081 B.S., total 118 building having plinth area >1000sq.m took plinth level permission, 95 took permission for superstructure construction. Among 95 buildings 76 were under construction and 19 were completed with area greater than 1000sq.ft. Stratified random sampling was carried out for the sample.

Table 1: List of Population and Sample

S.N.	Respondent types	Popln.	SampleSize	Sample %
For Objective-I				
1.	Total Permitted Building	95	49	51.57%
a.	Completed Buildings	19	10	52.63%
b.	Buildings under construction	76	39	51.32%
For Objective-II				
2.	Masons		32	

Result & Discussion:*Objective-I*

The first objective of the study is to check the compliance status of the building which are completed and are under construction after getting building permit from the Ghorahi Sub-Metropolitan City. The parameters for compliance check in completed buildings and buildings under construction are different. For constructed buildings compliance checklist has been prepared based upon the checklist prepared by Municipality for providing building construction certificate whereas compliance checklist for under construction based upon the compliance check handbook of Lalitpur Metropolitan City and Status of Building Code Compliance of Karyavinayak Municipality and Sisne Rural Municipality Rukum (East).

Table 2: Comparison of Compliance in Ghorahi Sub-metropolitan city, Godawari, Sisne, and Birendranagar Municipalities of constructed Building.

Parameter	Ghorahi Sub-metropolitan city		Godawari Municipality		Sisne Rural Municipality		Birendranagar Municipality	
	Compliance (%)	Non-compliance (%)	Compliance (%)	Non-compliance (%)	Compliance (%)	Non-compliance (%)	Compliance (%)	Non-compliance (%)
Column Size and Position	100	0	100	0	85.2	14.81	90.9	9.1
Beam Size and Position	60	40	93.58	6.42	7.4	92.6	40.9	59.1
Plinth Area Length- Breadth	70	30	64.1	35.6	3.7	96.30	68.2	31.82
Room size	40	70	51.28	48.72	3.7	96.3	59.1	40.91
Staircase size and position	50	50	87.18	12.82	7.41	92.59	27.3	72.73

Among the four study areas, Ghorahi Sub-Metropolitan City exhibited the highest level of compliance, with 100% adherence in column size, 60% in beam size, 50% in staircase dimensions, 70% in plinth area, and 40% in room size. In contrast, Godawari Municipality & Birendranagar Municipality demonstrated a moderate level of compliance, achieving (100 & 90.9%) conformity in column size, (93.58% & 40.9%) in beam size, (87.18% & 27.3%) in staircase size, (64.1% & 68.2%) in plinth area, and (51.28% & 59.1%) in room size respectively. Meanwhile, Sisne Rural Municipality recorded the lowest compliance, with beam size, plinth area, room layout, and staircase dimensions each showing less than 10% compliance with approved design standards.

Table 3 : Comparative Study of Ghorahi with Godawari, Birendranagar and Sisne Municipality of under-construction buildings

S. No	Description of Parameter	Ghorahi Sub-Metropolitan City		Godawari Municipality		Sisne Rural Municipality		Birendranagar Municipality	
		C (%)	NC (%)	C (%)	NC (%)	C (%)	NC (%)	C (%)	NC (%)
1	Depth of Excavation	100	-	92.3	15.4	100	-	100	-
2	Foundation Construction								
a	Size	100	-	84.6	15.4	100	-	100	-
b	Rebar placement and Size	80	20	100	-	100	-	100	-

c	Strap beam	100	-	100	-	100	-	-	-
3	Column Size and Position	100	-	100	-	100	-	90.9	9.1
4	**Beam Size and Position**								
a	Tie beam	100	-	-	-	100	-	100	-
b	Plinth Beam	100	-	61.5	38.5	100	-	100	-
c	Floor Beam	68.18	38.81	90.38	9.62	77.78	22.22	70.59	24.59
5	Slab Thickness								
a	Floor Slab	100	-	98.07	1.93	100	-	64.7	35.3
b	Staircase Slab	61.29	38.7	84.61	15.39	77.78	22.22	88.23	11.77
6	Mix Proportion	5.4	94.6	24.39	75.61	-	100	-	-
7	**Reinforcement detailing**								
a	Foundation	80	20	100	-	100	-	100	-
b	Column	100	-	100	-	100	-	100	-
c	Beam	100	-	100	-	100	-	100	-
d	Slab	100	-	100	-	100	-	100	-
e	Staircase Slab	61.29	38.7	100	-	100	-	100	-
8	Stirrups	100	-	70.73	29.27	100	-	88.89	11.11
9	**Lapping Position of Bar**								
a	Column	54.54	45.45	68.29	31.71	-	100	38.89	61.11
b	Beam Top Bar	13.6	86.36	78.57	21.43	71.42	28.57	76.92	23.08
c	Beam Bottom Bar	13.6	86.36	75	25	71.42	28.57	76.92	23.08
10	Sill and Lintel Band	81.8	18.18	89.28	70.72	85.71	14.28	84.62	15.38

Where,

C= Compliance, NC= Non- Compliance

The sample core In Ghorahi Sub-Metropolitan City, columns and slabs exhibited high compliance (100% and 98%, respectively). Staircase slabs and beam lapping showed poor compliance, at 38.7% and 13.6%, respectively. These values are considerably lower than in Sisne (71.42%) and Birendranagar (76.92%). Concrete mix quality was a major concern across all municipalities, with compliance as low as 5.4% in Ghorahi and 0% in Sisne municipality.

Objective-II

Characteristics, Awareness and Capabilities of Construction Contractor/Masons

The second objective of the study was to study the characteristics, awareness, and capabilities of construction contractor/masons towards building code compliance in construction of residential building in Ghorahi Sub-Metropolitan City. This objective defines the existing level of awareness

and capabilities of construction contractor and masons involved in building construction in Ghorahi Sub-Metropolitan City. This also helps to traces the reasons behind non-compliance of building code.

Table 4: Years of Experience of Mason

S. N	Experience in Years	Frequency	Percentage
1	Up to 5 Years	6	17.14
2	5 to 10 Years	2	6.25
3	10 to 15 Years	10	31.25
4	>15years	14	43.75

Above table shows that the majority of masons (43.75%) more than 15 years of experience, while a smaller percentage (6.25%) have 5 to 10 years of experience. The rest have either less than 5 years (17.14%) and (18.75%) have 10 to 15 years of experience.

Table 5: Training Involvement of Mason

S. N	Involved in Training	Frequency	Percentage
1	Yes	15	46.87
2	No	17	53.13

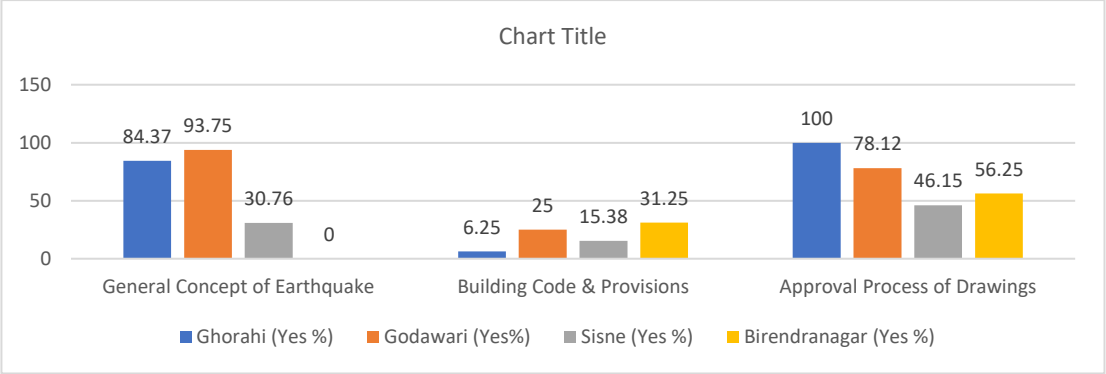
The data highlights the participation of masons in training programs. Also, indicates a significant gap in skill development, with almost more than half of masons relying on practical experience rather than structured learning.

Table 6: Academic Qualification

S. No	Academic Qualification	Frequency	Percentage
1	Literate	18	56.25
2	Under SLC	8	25.00
3	SLC	6	18.75

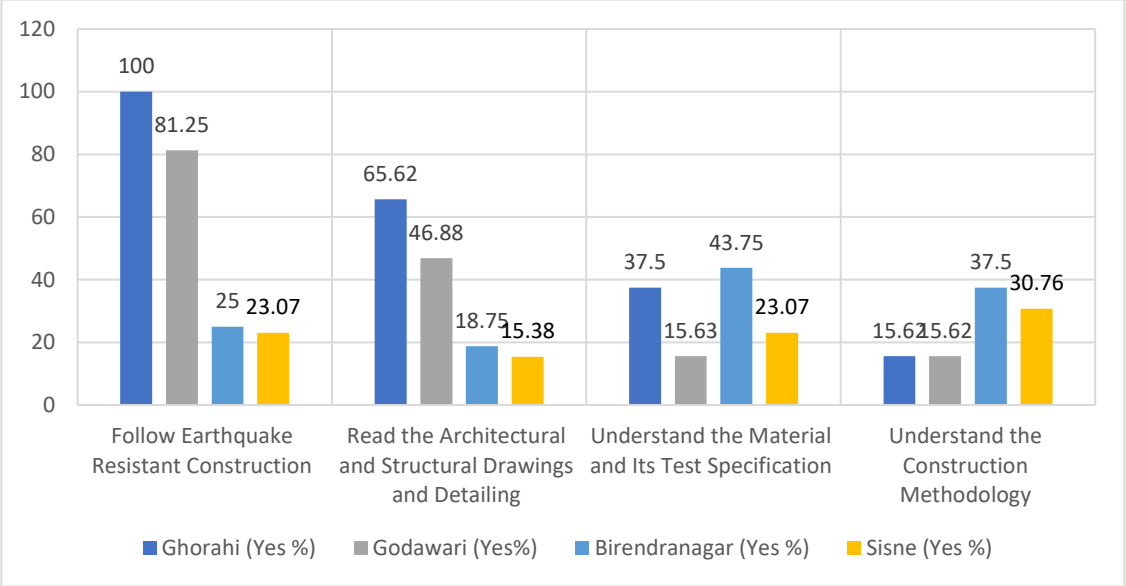
The data reveals that the majority of masons involved in building construction have limited academic qualifications. Quarter of them (25%) have an education level below the School Leaving Certificate (SLC), while 56.25% are only literate with no formal schooling beyond basic literacy. A smaller proportion, 18.75%, have completed SLC.

Fig. 2: Comparision of Awareness of Mason of Ghorahi with Godawari, Sisne and Birendranagar



Masons in Ghorahi demonstrated high awareness of earthquake phenomena (93.75%) and municipal approval procedures (78.12%), but showed limited knowledge of building code provisions (25%) and earthquake-resistant design principles (62.5%).

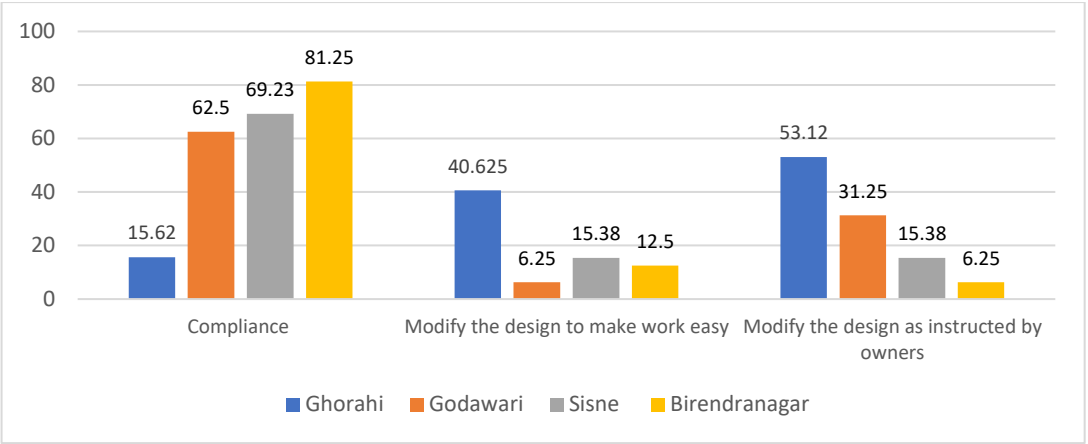
Fig. 3 : Comparision of Capabilities of Masons of Ghorahi with Godawori, Sisne and Birendranagar



Masons in Ghorahi & Godawori shows excellence knowledge in earthquake-resistant practices (100% & 81.25 respectively) and average in drawing interpretation (65.62% & 46.88 respectively), but demonstrated limited understanding of construction materials (37.5%) and low literacy in construction methodology (15.62%). Whereas, Birendranagar and Sisne shows worst case in earthquake-resistant

practices and drawing interpretation. All four local level shows less that average understanding of material testing and construction methodology.

Fig. 4: Comparision of Perspective of Masons of Ghorahi with Godawari, Sisne and Birendranagar



In Ghorahi, only 15.62% of masons adhered strictly to building designs, while approximately 53.12% modified designs based on owner requests. In Sisne, compliance was similarly more than at 69.23% and altering designs for owners is about 15.38%. Birendranagar exhibited the highest compliance, with only 81.25% following designs and 6.25% making modifications as requested by owners.

Conclusion:

Compliance with the NNBC and building bylaws in Ghorahi Sub-Metropolitan City remains insufficient. Among ten completed buildings, only three fully conformed to the approved designs, with common deviations observed in plinth area, room dimensions, beam position, and staircase construction. While under-construction buildings demonstrated strong compliance in key structural components (100% for columns and 100% for slabs), major shortcomings were noted in concrete mix quality (94.6% non-compliance) and rebar lapping (54.54% in columns and 13.6% in beams compliance) and Curtailment & Lapping (90.1% non-compliance).

Nearly half of the masons (46.87%) have participated in some form of training, and a minority have education up to the SLC level (18.75%). Although their awareness of earthquake hazards is relatively high (84.37%), knowledge of building code provisions is notably low (6.25%). Compared to Sisne and Birendranagar, Ghorahi shows better performance in most indicators but still faces persistent challenges such as inadequate concrete mixing and improper rebar lapping in structural elements.

Recommendation For Further Study:

a) Similar studies should be conducted in other municipalities and rural municipalities in Nepal.
b) Similar study on steel structures should be conducted since their use has increased nowadays.
c) Comparison of steel structures and RCC structures in compliance of building code should be carried out.

Limitations:

a) Only residential design RCC buildings plith area >1000 sq.ft. is considered for the study.

b) The study is focused in identifying the degree of compliance of residential building only.
c) The study covers only limited residential buildings of GSMC due to time and resources constraints.

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