Far Western Review
A Multidisciplinary, Peer Reviewed Journal
ISSN: 3021-9019
DOI: https://doi.org/10.3126/fwr.v1i2.62137
Published by Far Western University
Mahendranagar, Nepal

Study of Common Construction Practices and Structural Defects in RC Buildings in Darchula District Far-Western Nepal

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Abstract

This paper presents the common construction and structural deficiencies noticed in Mahakali municipality Darchula. The RC building constructions are common in the Darchula district. The main objective of this study is to find existing structural and construction mistakes in RC buildings.Field observations, interviews with engineers, technical people, local house owners, photographs, reviews of works of literature, bye-laws, buildings code, etc. are taken to fulfill the objective ofthe study. This paper examines the cause and effects of faulty construction practicesand structural defects by using both analytical and numerical methods. Structural defects are present in the RC buildings due to improper construction methods, poor use of bye-laws, poor workmanship, do not consult with professionals, corruption, lack of training, etc. The results show that these structural defects and faulty constructions practice may lead to serious failures of structures during strong earthquakes. This study provides relevant information on the building's collapse in a recent earthquake (Gorkha 2015) and the major cause of failure of RC buildings to compare the defectspresent in existing RC buildings inthe Darchuladistrict. The results concluded that almost 48% of buildings have column sizes less than 300mmx300mm, 24% of buildings have poor beam-column joints and 11% of buildings are soft storey and irregular building shapes. The numerical results pointed out that non-engineered buildings show poor seismic performance, poor seismic capacity and failure mechanism. The study strongly recommended that to prevent future hazards, the construction of buildings should follow the building's laws and codes and also should be ensured by the municipality and other government bodies also provides sufficient training and knowledge in the local level. To improve the existing structures, it is important to increase the strength capacity and ductility of the joint by providing a suitableretrofitting process or maintenanceprocess.

Keywords: Darchula, structural defect, earthquakes, flood and landslide, collapse, capacity curve

Introduction

The collision between the Indian and Eurasianplates, create the Himalayanregion in Nepal. It means Nepal is located highly seismically active zone (global seismic hazard maps the zone factor is IV).Due to the Indian plate lying under the Himalayas, the Darchuladistrictis susceptible to a larger-scale earthquake.

According to Nepal's standard, Nepal is divided into different seismic zones, whichare based on local seismic hazards. ForMahakalimunicipality, the zone factor is0.3. Numbers of seismic events such as 1833, 1934, 1936 and 2015 were observed in the Himalayas of Nepal and have claimed enormous loss of life and property. On 25 April 2015, the Gorkha earthquake having a magnitude of 7.8 occurred in Nepal. Almost 498,856 buildings completely collapsed and 256,697 buildings were partially damaged by these earthquakes. Researchers (Gautam & Chaulagain, 2016) analyzedGorkha earthquake and outline the lessons learn from this earthquake where, researchers recommended that it is needed to improvements in building code to assure structural performance during future earthquakes. The structures were damaged due to the short columns effect, stiffness deficiencies and load accumulation in upper stories andit is observed that almost 6.7% of RC buildings were damaged without collapse("NPC (National Planning Commission)," 2015). (Gautam et al., 2015) observed the Gorkha earthquake and its effects on structures. They found that the failures of the structures were due to many constructions and structural deficiencies in the structures. Similarly, (Ankeli et al., 2016)Studied the earthquakes and their effect on the structures in Nigeria and pointed the causes of failure.(Chaulagain et al., 2013)compared the 3 storey buildings with four different categoriesandconcluded that current construction practices types of buildings were under-designed. Several researcheshaveshown that the lack of implementation of code and bye-laws are the main reason behind the increasing collapse of structures during earthquakes (Anhorn et al., 2015; Giri, 2013; Mishra, 2019; Sehgal apoorva., 2017). It was also observed that low-quality materials used in construction sites lead to building defects and to ensure a good quality of work it is important to use the acceptable material in construction works(Ahzahar et al., 2011).Not only earthquakes, floods and landslides (Darchula 2013(Paudel et al., 2013),Melamchiriver flood (2021)(Gautam et al., 2022))also destroy buildings. One study (Kumar et al., 2012)studied the seismic hazard and risk assessments of Nepal with the help of GIS platformand this study found that the high percentage of permanent houses in the five districts are Darchula, Kathmandu, Doti, Baitadi and Baglungwere exposed to a very high hazard zone.

Therefore, it is important to know the conditions of the building, defects if there, and construction practices to predict the venerability level or damage in the case of future strong earthquakes in already existing buildings. This paper examines the structural defects and faulty constructions practice used in Darchula, especially in Mahakali municipality. The study correlated the building's failures in past earthquakes,floods and landslides withthe present existing building by using analytical and numerical analysis methods. The observed structural deficiency and faulty construction practices are compared with past collapse and partially collapse buildings due to the earthquakes and justice the observed field data and help to depict the damage modes, which could be helpful for future efforts to maintain the earthquakes resisting buildings.

Methodology

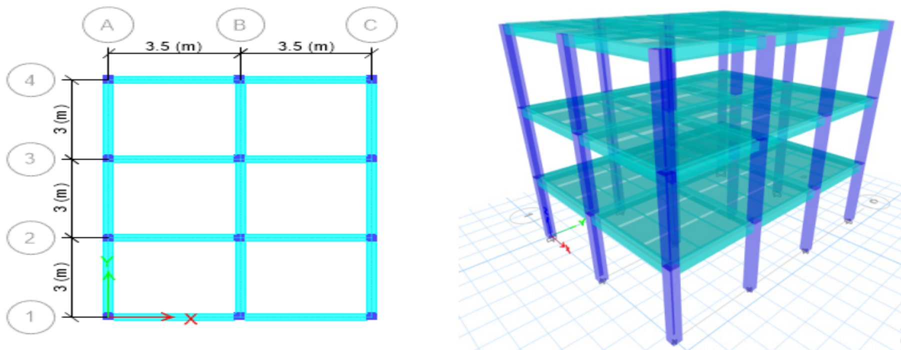
To fulfill the objective of this study, the primary data are collected by field visits, observation of buildings, Photographs, videos, doing questionnaires to address the issues arising in the buildings constructions and the Implication of codes and bye-laws. The study area is MahakaliMunicipality, which is located in the Darchula district'sFar-western regions. Data are collected around this area. Questionnaire surveys were collected from house owners, municipal engineers, technical persons, and engineers. Nearly 467numbers of houses or buildings have selected. Secondary data were collected by observing the government policy documents, laws, guidelines, and research study. To verify the analytical data, numerical analysis hasbeen performed and where some models are selected.

Studied RC Buildings

Based on the surveyed data, the 3-storey RC buildings are selected for numerical analysis. The spacing of bays, storey height, columns, beam, seismicproperties etc. was selected based on the observation of buildings. The plan and 3D view of the case study buildings are shown in Figure 1. The other buildings' properties, loading and seismic parameter are shown in Table 1. Two special moment resisting frames (SMRF) structures NBC (designed based on Nepal standard)and IS (designed based on Indian standard) modelsare used to compare to the other models M1 to M6 (non-engineered) that are ordinary moment resisting frame (OMRF) building and other structural properties are as shown in Table 2.

Figure 1

Building Geometry



(a) Plan of building (b) 3D view of RC buildings

Table 1

Material, loads and seismic parameters of the selected buildings.

Material properties			
Grade of	Concrete	M20	For all models
	Steel	415 Mpa	
modulus of Elasticity of	Concrete	22.36 Gpa	
	Steel	200 Gpa	
Loads			
live load on floor		2kN/m2	For all models
live load on the roof		1.5 kN/m2	
Finishing in roof load		1 kN/m2	
Weight of the wall on each floor		11.2kN/m	
Weight of parapet wall in the roof		4kN/m	
Seismic factor			
seismic zone (Indian standard- IS)		V	For all models
Zone factor according to IS (Z)		0.36	
importance factor for all models (I)		1	

Type of soil	II	
Response reduction factor R (SMRF)	5	For models NBC and IS
Response reduction factor R (OMRF)	3	For models M1 to M6

Table 2

Models information for case study RC buildings.

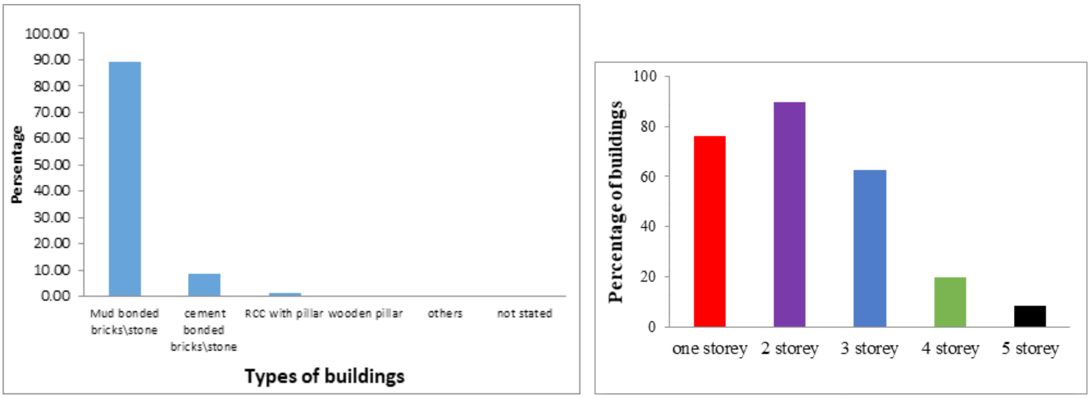
Models	Size of column (mmXmm)	Reinforcement used in column	Tie bar (in diameter)	Size of Beam (mmXmm)	Slab depth	Storey height
NBC	300x300	4-12d+4-16d (1.4%)	8	250x300	100 mm	3m
IS	300X300	8-16d (1.79%)	8	250x300		
M1	300x300	4-12d (0.5%)	6	230x250		
M2	300x300	4-16d (0.89%)	6	230x250		
M3	300x300	6-12d (0.75%)	6	230x250		
M4	230x230	4-12d (0.86%)	6	230x230		
M5	230x230	6-12d (1.28%)	6	230x250		
M6	250x230	4-16d (0.75%)	6	230x250		

Results and Discussion

The results show thatPeople living in Darchula now replacing the traditional construction practice with modern practices. According to the National Population and Housing Census (NPHC) 2011 in Darchula almost 24,604 households were reported. However, after 10 years,the new NPHC 2021 shows atotal household number of 25,200 which shows that only 596 household number are increased in 10 years in Darchula. In2011, almost 89% of houses are mud-bonded bricks\stone and 1.41% of buildings wereRCC buildings, which is very low at that time as shown in Figure 2 (a).

Figure 2

(a) NPHC 2011 for Darchula district, (b)The percentage of RC buildings according to the number of storey



(a)   (b)

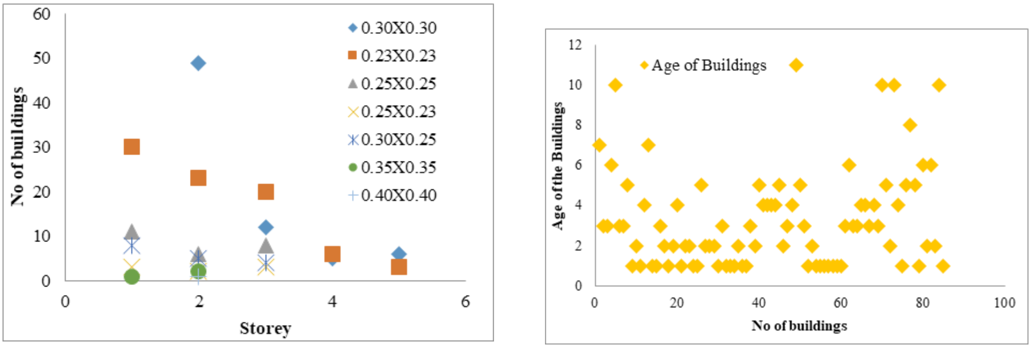
While observing RC buildings in different places different types of deficiencies are noticed and the following deficiencies have been focused on in thisstudy.

National Building Code (NBC) and Standard

Mandatory rules of thumb (MRT)where NBC 201, 202 and 205provide the ready-to-use provision such as dimension, detailing of the beam, column, and size of the room and it hascommonlyused in owner-built houses in Nepal. To construct an earthquake resisting buildings NBC recommended some improvements after Gorkha earthquake (2015) in code and minimized the size of columns should be 300mm x 300mm (minimum rebar of 4-12mm diameter bar and 4-16mm dia) for up to three storey's with a column to columns span should be less than 4.5m. While observing the column size with their storey of 238 buildings different types of column sizes were noticed which is as shown in Figure 3(a). Only 43% of buildings are constructed with 300mmX300mm size columns and almost 48% of buildings have a column size of less than 300mmX300mm. It is also observed (see Figure 3(a)) that nearly 18% of buildings are greater than 2-storey buildings where smaller (less than 300mm) columns are used. This shows that people have no sufficient knowledge of building laws and the building owner constructed their building without getting permission from the municipality. While understanding the people's views on it, people feel lengthy and costly (taxes, engineer cost) to get permission for the construction of buildings.Figure 3(b) shows the age of buildings and the data shows that most the buildings are constructed recently (almost 6 years) but people do not follow NBC properly.

Figure 3

(a) The relation between the size of columns with storey number (b) Age of buildings



(a) (b)

Beam Columns Joint

InMahakali municipality, most of the construction of the column-beam joint is not monolithic. Figure 4 shows the construction of one axis beam resting on another axis beam in the columns. It is common in this area. While observing the 467 buildings, 24% of buildings have poor beam-column joints. Due to this, the connection of beams and columns seems to be venerable to earthquakes (Varum et al., 2018). The building data also shows that some buildings have small column sections (230mmX230mm) with less than a minimum 0.8% rebar and almost the same beam section that's don't follows the rules of the code. Due to this, there are maximum chances to observe the weak-column strong-beam design. It is also observed that insufficient stirrup spacing near the joint, small diameter of the stirrup,honeycombing structure and weak confinement of RC sectionin the RC buildings in Mahakali municipality.

Figure 4

(a), (b) Beam-column joints defects and column reinforcements is short for the continuity of the columns in the upper floor (c) Poor beam-column joints (d) Poor joints

(a) (b) (c) (d)

Reinforcement Detailing

Thenumber of main reinforcements in beam and column are undervalued. It is observed that in columns 4-10mm bars are provided. Inthe Gorkha earthquake, it was observed that the maximum number of buildings, which were collapsed, due to the use of less amount of rebar(Gautam et al., 2015). Sincethe required number of reinforcements should be, provide. It hasbeen observed that 6 and 8mm diameter barswere used as a stirrup and spacing is 0.15m or even more.Figure 5 shows the different types of column sections used in Mahakali municipality. However, in some governmental buildings, 350 mmX350mm and 400mmX400mm size of columns are noticed and also a good amount of reinforcements are provided on it. The spacing of stirrups near the joints and lap splices length are not proper as shown in Figure 6.No proper structural drawingsare used while the construction of buildings. Poor construction work and poor concrete quality also observed (see figure 6(d).

Figure 5

Detailing of columns used in RC buildings located in Mahakalimunicipality Darchula

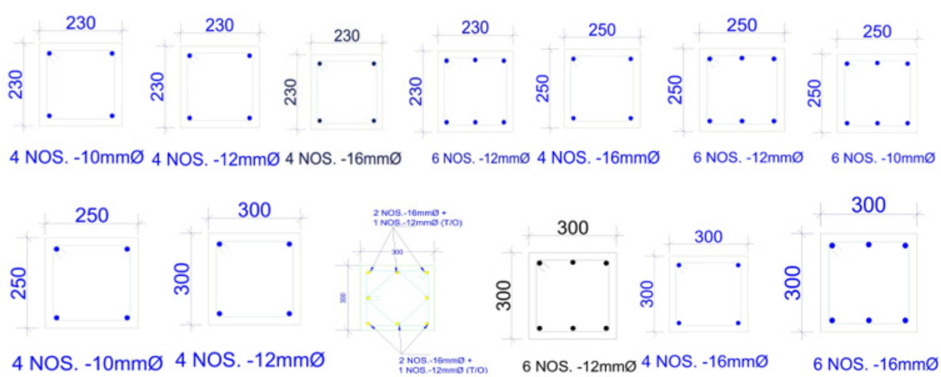


Figure 6

(a) No proper anchorage provided in beam-column joints (b) Stirrups spacing near the joints is more (c) No proper cover and spacing of stirrups maintained (d) Poor beam-colimn joint

(a) (b) (c) (d)

Soft Storey Buildings

While observing the different types of buildings, almost 80 to 90% of private buildings are constructed for commercial purposes and having with shutters. Lower storeyis open and upper storey are with infill brick or block masonry walls, some buildings step back buildings which cause the soft storey as shown in Figure 7. It isnoticed that almost 11% of buildings are as soft-story buildings. It hasbeen observed that during several earthquakes soft-story failure is one of the commoncauses of collapse (Gautam et al., 2015). In the soft-storey buildings, the size of the columns are 230mmX230mm and hasa minimum percentage of steel (<0.8%), which further shows the buildings are seismically hazardous.

Figure 7

(a) Softstorey in the mid storey of the buildings (b) Soft storey, floating columns, (c) Softstoreyand short column effects (d) Soft storey

(a) (b) (c) (d)

Load Accumulation in Upper Stories and Floating Columns Effect

It is observed that in the upper stories the loads are increased by constructions of extra area loads which cause floating columns effects and due to the discontinuity of load path during earthquakes, the lateral load is not effectively transferred in beams, columns and ultimately in foundations. Due to the incremented loads in the upper story as shown in Figure 8overturning moments developed in columns and there is a chance to buckle the columns in the lower storey and damage may be observed. Such types of buildings are designed and the use of codel provisions should be properly but in Darchula it is very difficult to see the implementation of laws and codes in buildings.

Figure 8

(a) load accumulation on the upper floor, (b), (c) and (d) Floating columns

(a) (b) (c) (d)

Seismic Gaps in Buildings

Leavingthe proper dilatation gaps between structures helps to minimize the pounding effects in buildings during earthquakes. It is observed in the city area, buildings are constructed adjacent to each other without providing seismic gaps (as shown in Figure 9(a)). Differentstoreyheights, weights, workmanship, and agesof the structures cause high load impact on eachother and it may cause the failure of structures. Figure 9(b) shows that a seismic gap hasbeen maintained in an L shape building as 15cm but due to lack of supervision, one part of the beam is joined with columns of another part of the building.

Figure 9

(a) No seismic gaps in each building (b) Gap maintained but the beam of one part of the building is connected with the column of another part of the building

(a) (b)

Poor Construction Techniques

It is observed that the size of coarse aggregate is 40mm to 70mm (see in Figure 10 (a),(b)) and for this reason, they used more fine aggregates (1:3:4) is noted. Improper mixing of concrete and water cement ratioare observed. Due to poor construction technology in beam, slab and columns,thesegregation, honeycombing and bleeding in concrete members are noticed. Due to this, the main reinforcements are visible and even corrosion is common on it. Patchingin columns hasbeen observed and to cover it plaster was applied on it. Almost the total height of columns (greater than 1.5m) is cast in a single stage, as shown in Figure 10 (c).The materials used in construction also substandard, cement used in construction sometimes used 3-month-old types of cement as shown in Figure 10(d).Different types of blocks are used and are made by local or house owners so it is very difficult to know their strength, specific gravity weight, and another parameter (see Figure 10(e)). This makes load uncertainty in buildings.

Figure10

(a) and (b) Non-uniform aggregate (c) Cements past flow outside from lower portion of formwork (d) Cement lump has been observed in site (e) Unknown specific gravity of the concrete block which is standard material

(a) (b) (c) (d) (e)

Irregular Shape and Cold Joint Building

Almost buildings are non-engineered buildings and these buildings are constructed without design and supervision. Due to a lack of a monitoring system, owners themselves add a storey or construct buildings irregularly in shape by hiring local contractors. Asymmetrical structuresbuilt with the shape of the land plot are commonly observed in Darchula. In past, it was observed that such types of structures sustained heavy damage in Gorkha 2015 earthquakes in Nepal (Varum et al., 2018). Cold joints or construction joints are provided in the structures during the construction stages. However, the experimental analysis shows that the first cracks are observed in cold joint locations(Chaulagain et al., 2015). In Darchulait is observed that old buildings and new buildings are jointed, where beams and slabs in the old building are jointed with new beams and slabs, which formed cold joints. It is observed that too short column and beam reinforcements are used for continuity of buildings (old to new construction) as shown in Figure 11.

Figure 11

(a) Too short reinforcements left for continuity of columns (b)Beam rebar is left to make a cold joint in the beam in the future

(a)   (b)

Lack of Setbacks From Highways

In Darchula it is common for the construction of buildings too near the Mahakali highways. Without leaving the proper right of way of highways, private RCstructures are observed near the roadside. A maximum of these buildings are illegal constructions and it violates the Nepal road standard.

Soil Pressure on the Back or Front Side of Buildings

In Khalanga bazaar, the slopping side is cut down and stone walls or blocking is usedto construct the buildings. During an earthquake, it is a maximum possibility ofthe collapse of the non-structural walls due to the soil pressure in the wall. Extra lateral pressure is may be induced in the wall and if the wall is not properly designed, the maximum possibility of failure of the wall. However, ithasbeen observed that in Darchulaslopping side of the buildings have been constructed withnon-structural wallsas shown in Figure 12.

Figure 12

(a), (b) Soil pressure induced in the wall (c) Soil pressure and risk of landslide for buildings (d) Soil pressure in the back-side of buildings

(a) (b) (c) (d)

Flood and Landslide Risky Buildings

Flood may sweep the whole structure when improperurban planning and sustainable design process is used. In Darchula the flood is observed inthe Mahakaliriver(Paudel et al., 2013). In 2013 one of the massive floods was observed and that flood sweeps 12 government buildings, 156 private buildings, playgrounds, halls etc. even district hospital buildings were partially swept out bythe flood.Also recent flood in Darchula 2022, distroied life, property and land(see Figure 13) so it is very important that understand the flood risk area and hazardous areas. It hasbeen observed that many buildings are constructed near the riverside, and landslide risk area (see Figure 13).

Figure 13

(a) and (b) Buildings collapsed due to the Darchula flood in 2022 (c) Flood hit the wall in buildings

(a) (b) (c)

Causes of Building Deficiencies

In Mahakali municipality, the following causes of buildings deficiencies are noticed:

- Lack of supervision
- Corruption
- Lack of use of modern construction technology
- Lack of training
- Lack of knowledge of building construction methodology
- Unmanaged planning of urban and land

Linear Static Analysis

Every eight models are firstly checked by using linear analysis. The equivalent static analysis and response spectrum analysis are performed in the models. The following results are obtained based on linear analysis:

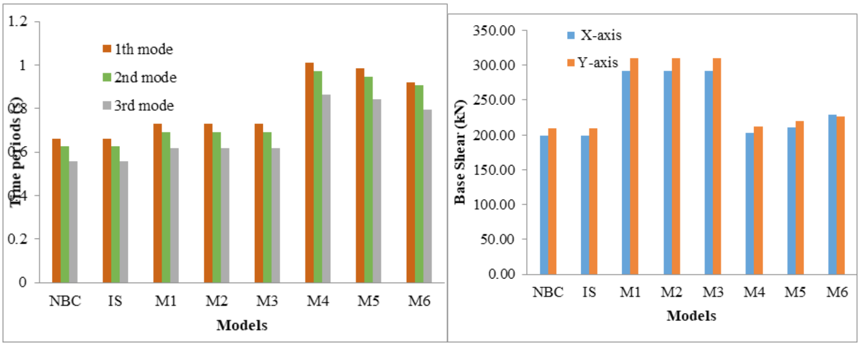
Fundamental Time Periods, Base Shear and Stiffness of the Structure

Figure 14(a) shows the model NBC and IS have similar natural periods and also value is minimum as compared to the other models. It is observed that when the size of the column and reinforcements of the columns decreases, the fundamental time period increases, it is because the stiffness of the columns increases asthe size of the column decreases as shown in Figure 15. Model M4 (230x230 and 0.86% rebar) shows the almost maximum natural period which is 1.012 s.

In the results, it is observed that models NBC and IS have the same values of shear force (see in Figure14(b)) . Even though the column size of the models IS, NBC and M1 to M3 have the same 300x300mm, the base shear value is more in the M1 to M3 models which are 292.43kN, it is because it is assumed that models M1, M2 and M3 are the OMRF (see in Figure 14(b)). However, the well-designed model IS and NBC has been assumed SMRF.It is noticed that as decreasing the size and percentage of reinforcements in columns, the storey stiffness of the structure increases as shown in Figure 15.

Figure 14

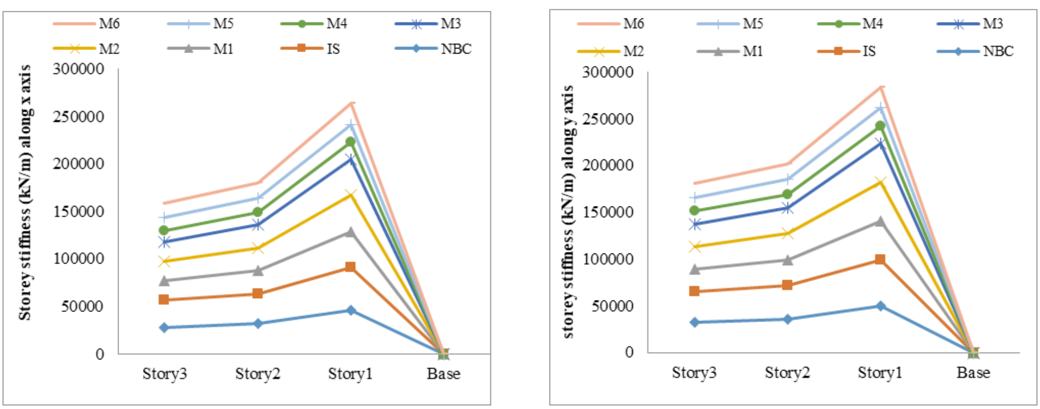
(a) Time periods of the building models (b) Base shear (KN) of the building models



(a) (b)

Figure 15

Storey stiffness of each model



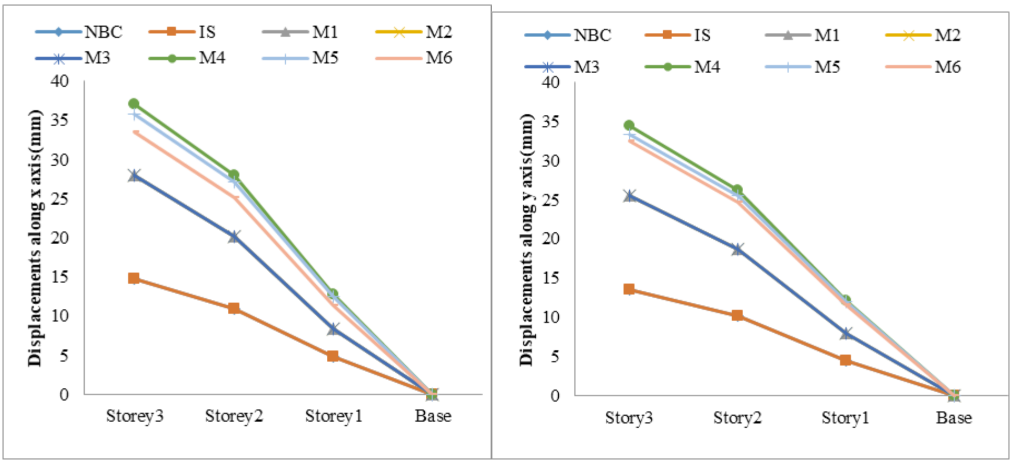
(a) Storey stiffness along the x direction (b) Storey stiffness along the y direction

Storey Displacements and Storey Drift

It is noticed that minimum displacements are observed in models NBC and IS which is almost 14.7mm and maximum displacement is observed in model M4 which is 37mm as shown in Figure 16. Almost 40% increments in displacements have observed while column size and reinforcements were decreased in M4 models.The Indian standard (IS 1893. Part 1, 2016) suggested that the inter-story drift should be limited to 0.004. Figure 17shows the maximum inter-story drift of each model in both the x and y directions. It is noticed that only models NBC and IS (nearly the same value) have minimum inter-story drift however the other models have a value near or more than 0.004, which is the maximum limited value as suggested by Indian standard (IS 1893. Part 1, 2016).

Figure 16

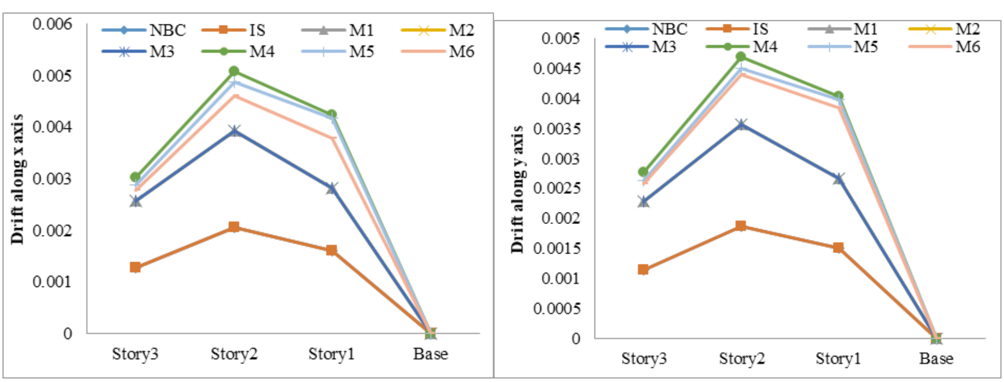
Storey displacements of each model



(a) Displacement along x-axis (b) Displacement along y-axis

Figure 17

Inter-storey drift of each model



(a) Drift along the x-axis (b) Drift along the y-axis

Nonlinear Analysis

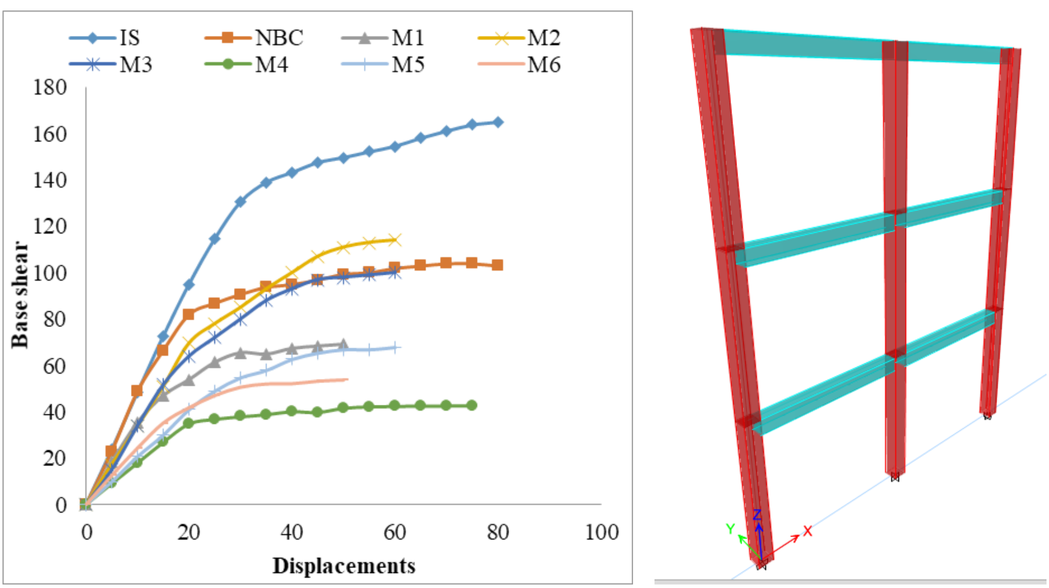
To check the seismic capacity of the structure, nonlinear or pushover analyses were performed in each model. The two-dimensional along the X-axis is only considered and pushover load is applied along the x-axis. The pushover analysis was performed in ETABS software where the plastic hinge length and other nonlinear parameters were defined in this software.

When the lateral force is increased and displacementsare noticed in every increment of lateral load also known as pushover analysis the capacity curve is obtained as shown in Figure 18(a) and Figure 18(b) shows the 2D frame. It is obtained that models which are designed by using the Indian standard (IS model) show ahigh capacity value as compared to the NBC models. These two models (IS and NBC) are identical in all senses only the percentage of reinforcements was more as shown in Table 2. It is also noticed that model M4 has minimum capacity. While observing the curve it hasbeen obtained that model NBC, M1, M2, and M3 have similar types of capacity curves. The curve results that only IS models have sufficient capacity and are more ductile.

While observing the failure pattern of the structure it hasbeen observed that models M1 to M6 have poor performance as shown in Figure 19. While noticing the formation of the hinge in the beam, and columns, some models show the weak column strong beam, which is just opposite to the design philosophyof strong column weak beam.

Figure 18

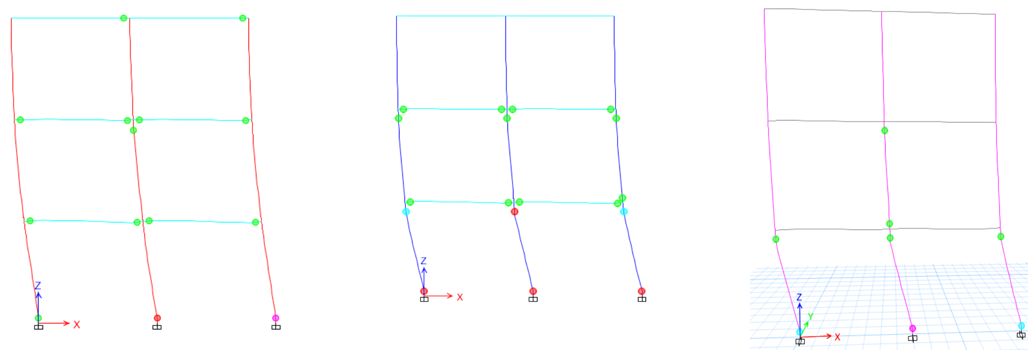
(a) Thecapacity curve of each model (b) 2dimension models for pushover analysis



(a) (b)

Figure 19

Collapse mechanisms for selected models



(a) IS (b) NBC (c) M1

Conclusion

After the observations of around 467 RC buildings, different types of structural and construction problems are notified. Literature reviews show that these types of mistakes in RC buildings cause serious effectson life and property. To verify the many deficiencies presented in the RC buildings, this article observes the seismic performance of the three-story buildings. The following additional results are noticed:

- As results show that, many buildings are non-engineered buildings so reinforcement detailing, size of columns used in structure and reinforcements used in beam and columns are improper and undervalued.
- It is concluded that 19 % of buildings having more than three storey and48% of buildings have less than 300mmX300mm size of columns which means 48% of buildings didnot follow the Nepal buildings codes.
- It is found that 24% of buildings have Poor beam-column joints, and 11% of the buildings were soft-storey and irregular in shape.
- The buildings are constructed very near the rivers, most of buildings are in risk of flood and landslide.
- The numerical results show that structures having 230mmX230mm and 250mmX230mm size of columns show very poor results and fail during the earthquake loading.

- The maximum displacements and inter-story drift is satisfactory for the models NBC and IS only. So that non-engineered buildings must be upto three storeys,column size should be a minimum of 300mmX300mm and havea minimum 4-12mm dia +4-16mm dia bar.
- Nonlinear analysis shows that only IS buildings show very good capacity and ductility behaviors. However, NBC buildings also show a satisfactory capacity for lateral loads.
- Hinge formation in the beam and columns shows that the models M4 to M6 do not show good results where beams fail first and then columns. These models do not follow the design philosophy of strong column weak beams concepts.
- Overall results show that columns having a size 230mmx230mm have no sufficient capacity and ductility to resist the lateral loadings.

The study, therefore, recommended that people living in Darchula should be constructing their houses properly by using an engineer or technician or following the municipal and buildings code rules to get sufficient strength and earthquakes resisting buildings. The governments should be involved in construction industries, rulemakings for buildings, and checking the quality of the material and planning of land. Training is an important parameter and should be provided to the professionals and technicians of building construction. It is also recommended that the structure, which is not properly designed, and has un-standardize structural members should be identified and to make them earthquake-resisting structures, a proper re-strengthen or retrofitting process should be used.

References

Ahzahar, N., Karim, N. A., Hassan, S. H., & Eman, J. (2011). A study of contribution factors to building failures and defects in construction industry. *Procedia Engineering*, *20*, 249–255. https://doi.org/10.1016/j.proeng.2011.11.162

Anhorn, J., Lennartz, T., & Nüsser, M. (2015). Rapid urban growth and earthquake risk in Musikot, Mid-western hills, Nepal. *Erdkunde*, *69*(4), 307–325. https://doi.org/10.3112/erdkunde.2015.04.02

Ankeli, T., Zabidi, A., & Razak, A. (2016). Building collapse in nigeria: Issues and challenges. *Conference of the International Journal of Arts & Sciences*, *09*(01), 99–108.

Chaulagain, H., Rodrigues, H., Jara, J., Spacone, E., & Varum, H. (2013). Seismic response of current RC buildings in Nepal: A comparative analysis of different design/

construction. *Engineering Structures*, *49*, 284–294. https://doi.org/10.1016/j.engstruct.2012.10.036

Chaulagain, H., Rodrigues, H., Spacone, E., & Varum, H. (2015). Seismic response of current RC buildings in Kathmandu valley. *Structural Engineering and Mechanics*, *53*(4), 791–818. https://doi.org/10.12989/sem.2015.53.4.791

Gautam, D., Adhikari, R., Gautam, S., Pandey, V. P., Thapa, B. R., Lamichhane, S., Talchabhadel, R., Thapa, S., Niraula, S., Aryal, K. R., Lamsal, P., Bastola, S., Sah, S. K., Subedi, S. K., Puri, B., Kandel, B., Sapkota, P., & Rupakhety, R. (2022). Unzipping flood vulnerability and functionality loss: tale of struggle for existence of riparian buildings. *Natural Hazards*, *0123456789*. https://doi.org/10.1007/s11069-022-05433-5

Gautam, D., Bhetwal, Krishna Kumar Rodrigues, H., Neupane, P., & Sanada, Y. (2015). Observed Damage Patterns on Buildings during 2015 Gorkha (Nepal) Earthquake. *In Proceedings of the 14th International Symposium on New Technologies for Urban Safety of Mega Cities in Asia*, *14*, 8.

Gautam, D., & Chaulagain, H. (2016). Structural performance and associated lessons to be learned from world earthquakes in Nepal after 25 April 2015 (MW 7.8) Gorkha earthquake. *Engineering Failure Analysis*, *68*, 222–243. https://doi.org/10.1016/j.engfailanal.2016.06.002

Giri, N. (2013). *Implementation of Nepal National Building Code Through Automated Building Permit System*. 8. https://www.preventionweb.net/publications/view/35258

IS 1893. Part 1. (2016). *Indian Standard Criteria for Earthquake Resistant Design of Structures: General Provisions and Buildings. New Delhi: Bureau of Indian Standards,.*

Kumar, A., Arambepola, M., Mechler, R., & Hochrainer-Stigler, S. (2012). Approach for national scale earthquake risk assessment: case study from Nepal. *In Proceedings of the 15th World Conference on Earthquake Engineering - WCEE*, 1–10.

Mishra, A. K. (2019). Structural Features for Earthquake-Resistant Load-Bearing Residential Buildings in Nepal. *Journal of Advanced Research in Geo Sciences & Remote Sensing*, *6*(1), 1–16. https://doi.org/10.24321/2455.3190.201901

NPC (National Planning Commission). (2015). *Post Disaster Need Assessment Vol. A and B.*

Paudel, P., Regmee, S. B., & Upadhyay, S. N. (2013). Overview of june 2013 Flood and Landskides with focus on Darchula Disaster. *Hydro Nepal*, *13*, 57–63.

Sehgal apoorva., J. bharat. G. . U. (2017). Existing scenario of building code implementation in newly formed "Nagarjun Municipality." *Asian Journal of Science and Technology*, *8*(11), 6751–6762.

Varum, H., Dumaru, R., Furtado, A., Barbosa, A. R., Gautam, D., & Rodrigues, H. (2018). Seismic performance of buildings in Nepal after the Gorkha earthquake. *Impacts and Insights of the Gorkha Earthquake*, 47–63. https://doi.org/10.1016/B978-0-12-812808-4.00003-1