Tribhuwan University

Institute of Engineering

Central Campus, Pulchowk

DEPARTMENT OF CIVIL ENGINEERING

A Project Proposal
On

Earthquake Resistant Analysis and Design of Multistoreyed Building

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Submitted To:

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Group Supervisor

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ABSTRACT

The main aim of the project is to structurally analyze and design a seismic resistant multistoreyed building. A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic sanitation and ventilation and daylight standards. The design of the building is dependent upon the minimum requirement prescribed for each of the above functions.

As per the recent following of the Gorkha Earthquake that occurred in 25th April, 2015, the construction of multistoreyed building has been of major concern. So proper selection of the building site is required. The analysis and design of our building is based on increasing the seismic capacity through proper configuration of the structure as well as proper designing and ductile detailing of structural elements.

The project will commence within the above mentioned criteria and the strength and serviceability will be checked. If the conditions are okay the final output of the project as detailed drawings will be obtained else certain changes in the design will be required.

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Introduction

We are interested in carrying out a project work on the analysis and design of an earthquake resistant building, which is one of the topics recommended by the Department of Civil Engineering for carrying out a project work on, for the fulfillment of the Bachelor in Civil Engineering program.

Nepal is located in a seismic zone and is prone to earthquakes. We have experienced several earthquakes in the past, the most recent one being the Gorkha Earthquake of April 25, 2015, which measured 7.8 on the Richter scale. Proper analysis and safe design of structures, therefore, carries great importance which is the main reason why we propose to perform a project on seismic resistant building design.

The design of the building will be based on the detailed plans of a proposed RCC building provided by the project supervisor. The design shall include the design of following components.

- Foundation
- Basement Wall
- Beams
- Columns
- Slabs
- Lateral load resisting systems
- Staircase

Salient Features

- Name of the Project: Seismic Analysis and Design of Multi-Storeyed RCC Building
- Location:
    - Region: Central Development Region
    - Zone: Bagmati
    - District: Kathmandu
- Type of Building: Apartment Building
- Structural System: Special Moment Resisting Frame
- Soil Type: ii
- Seismic zone: v
- No of Storey: 11.5 including basement
- Dimension of building:
    - Maximum length: 70'5"
    - Maximum Breadth 79'2"
- Type of Stair: Open Well
- Type of foundation: Raft Foundation
- Floor Height:
    - Basement: 9'10"
    - Typical: 10'6"
    - Staircase cover: 9'6"
- Infill wall: Brick Masonry
    - Main wall: 9"
    - Partition wall: 4.5"
- Design criteria: As per IS code
- Size of structural elements:
    - Beam: 12"*20"
    - Column:
    - Slab thickness: 6"
    - Depth of footing: 20"
- No of columns:
    - Basement: 42
    - Typical: 42
    - Staircase cover: 8

Objectives

The objectives of the project are listed below.

- Identification of structural arrangement of the plan.
- Re-modeling of the building for structural analysis.
- Detailed structural analysis of the building using computer software.
- Design of various structural components.
- Detailing of structural members.
- Better acquaintance with the code provisions for reinforced concrete design.
- Acquire knowledge on earthquake engineering.
- Estimating total cost of building construction.

Literature Review

Every engineering design is the outcome of the past experiences and observations. It is necessary to justify the result of the analysis and design properly with reference to the pre-existing standard results or the past experiences. Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its service life. Safe design of structures can be achieved by applying the proper knowledge of structural mechanics and past experiences. It is needed to provide authentic reference to the design made i.e. the design should follow the provision made in codes of practices. Use of codes also keeps the designer to the safe side in case the structure fails within its service life. For this design, certain references and criteria are taken from the literatures discussed below.

I. Nepal National Building Code (NBC:000- 1994):

Nepal National Building Code was prepared during 1993 as part of a bigger project to mitigate the effect of earthquakes on the building of Nepal. It deals primarily with matters relating to the strength of buildings. However, there are some chapters on site considerations and safety during construction and fire hazards. This code aims to bring uniformity to the building construction by providing some bye-laws and mandatory rules. But its development is relatively recent and it still lacks many documents required to support it. To compensate for this unavailability, the code frequently refers to Indian Standard codes. The four different levels of sophistication of design and construction that are being addressed in this National Building Code are as follows.

i. International state-of-art
ii. Professionally engineered structures
iii. Buildings of restricted size designed to simple rules-of-thumb
iv. Remote rural buildings where control is impractical.

This project belongs to the second part of NBC i.e. Professionally Engineered Structures. As the National Building Code defines the use of international codes which meets the requirements stated in NBC, different Indian Standard codes are used for the design and analysis purpose.

II. Indian Standard (IS) Codes of Practice:

For the analysis and design of the building references have been made to Indian Standard code since National Building Codes of Nepal do not provide sufficient information and refers frequently to the Indian standard codes. Indian Standard codes used in the analysis and design of this building are described below:

1. **IS:875- 1987 *(Reaffirmed 2003)*- Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures:**

   A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions.

The minimum requirements pertaining to the structural safety of the building are being covered in this code by way of laying down minimum designed load which have to be assumed for dead loads, imposed load, snow load and other external loads, the structure is required to bear. Strict conformity to loading standard recommended in this code claims to ensure the safety of the buildings and thereby reduced the hazards to life and property caused by unsafe structures as well as eliminates the wastage caused by the assumption of unnecessary heavy loading.
This code is divided into five different parts for five different kinds of loadings. The different parts of the code are:

Part 1: Dead Loads- Unit Weight of Building Materials and Stored Materials:

This part deals with the dead load to be assumed in the design of the building. These loads are given in the form of unit weight of materials. The unit weight of the materials that are likely to be stored in the building are also given in the code for the purpose of the load calculation due to stored materials.
This code covers the unit weight or mass of the materials and parts and components in the building that apply to the determination of the dead load in the design of building.
Table 1 of this code covers unit weight of the building materials and Table 2 of the code covers the unit weight of the building parts or the components.

Part 2: Imposed Loads

Imposed load is the load assumed to be produced by the intended use or occupancy of a building including the weight of moveable partitions, distributed, concentrated loads, loads due to impact and vibrations and dust loads (Excluding wind, seismic, snow, load due to temperature change, creep, shrinkage, differential settlements etc.)

This part of the code deals with imposed load of the building produced by the intended occupancy or use. Minimum imposed load that should be taken into consideration for the purpose of structural safety of the buildings are given in the code but it do not cover the incidental to construction and special cases of vibration, such as moving machinery, heavy acceleration from cranes hoist etc.

Part 3: Wind Loads

This part deals with the wind load to be considered when desigining the building, structure and component thereof. This code gives the wind force and their effect (Static and Dynamic) that should be taken into account when designing buildings, structures and components

thereof. In the code wind load estimation is done by taking into account the random variation of the wind speed with time.

Part 4: Snow Loads

This part of the code deals with snow loads on roofs of buildings. Roofs should be designed for the actual load due to snow or the imposed load specified in Part 2 whichever is more sever. Since location of the building is within Kathmandu Valley, there is no possibility of snowfall. Hence the snow load is not considered in the design.

Part 5: Special Loads and Load Combinations

This code loads and loads effects (Except the loads covered in Part 1 to 4 and seismic load) due to temperature changes, internally generated stress due to creep shrinkage, differential settlement etc. in the building and its components, soil and hydrostatic pressures, accidental loads etc. This part also covers the guidance for the load combinations.

2. **IS 1893 (Part 1): 2002 Criteria for Earthquake Resistant Design of Structures (General Provision and Building):**

   This code deals with the assessment of seismic loads on various structures and earthquake resistant design of buildings. Its basic provisions are applicable to buildings; elevated structures; industrial and stack like structures; bridges; concrete masonry and earth dams; embankment and retaining structures and other structures. Temporary supporting structures like scaffoldings etc. need not be considered for the seismic loads. It is concerned with the methods of determining seismic loads and the effects of various irregularities in a building can have upon its seismic response. This standard does not deals with the construction features relating to earthquake resistant design in building and other structures.

3. **IS 13920: 1993** ***(Reaffirmed 2003)*** **Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Force- Code of Practice:**

   This standard covers the requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist sever earthquake shock without collapse. The provision for the reinforced concrete construction given in the code are specifically to the monolithic reinforced concrete construction. For precast and prestressed concrete members, its use is limited only if they can provide the same level of ductility as that of monolithic reinforced concrete construction during or after earthquake. The code include the detailing rules for flexural members, column and frame member subjected to bending and axial loads and shear walls.

4. **IS 456: 2000** ***(Reaffirmed 2005)*** **Plain and Reinforced Concrete – Code of Practice:**

   This Indian Standard code of practice deals with the general structural use of plain and reinforced concrete based on Limit State Design Method. According to the code, plain concrete structures referred to those structures where reinforcement if provided is ignored for determination of the strength of the structure. This code does not cover special requirements for the structures like bridges, chimneys, hydraulic structures, earthquake resistance buildings etc. but allows the use of separate code for those structures in conjunction with this code.

5. **IS 4326: 1993** ***(Reaffirmed 2003)*** **Earthquake Resistant Design and Construction of Buildings – Code of Practice:**

   This standard deals with the selection of materials, special features of design and construction for earthquake resistant buildings including masonry construction using rectangular masonry units, timber construction and buildings with prefabricated flooring or roofing elements.

6. **IS 5525: 1969** ***(Reaffirmed 1990)*** **Recommendations for Detailing of Reinforcement in Reinforced Concrete Works:**

   This standard deals with the general requirements of detailing of reinforcement in reinforced concrete structures with some suitable modifications whenever necessary. This code includes the common method of detailing of reinforcement based on good practice with deviations made in special cases to comply with IS 456.

7. **IS 1642: 1989** ***(Reaffirmed 1994)*** **Fire Safety of Buildings (General): Details of Construction – Code of Practice:**

   This standard lays down the essential requirements of fire safety of buildings with respect to details of construction.

8. **IS 2950 (Part I): 1981** ***(Reaffirmed 1998)*** **Code of practice for design and construction of Raft Foundations:**

   Raft foundation is a substructure supporting an arrangement of columns or walls in a row or rows and transmitting the loads to the soil by means of a continuous slab with or without depressions or openings. Such types of foundations are found useful where soil has low bearing capacity. This standard covers the design of raft foundation based on conventional method (for rigid foundation) and simplified methods (flexible foundation) for residential and industrial buildings, store-houses, silos, storage tanks, etc., which have mainly vertical and evenly distributed loads.

III. Indian Standard Special Publications (SP):

For the clarification and explanation for the clauses and equations mentioned in Indian Standard Codes, Bureau of Indian Standard has published some special

publications including charts and tables for required values like material properties and explaining examples of designs. Following design aids will be used for the design of the structure:

1. **SP 16: *Design Aids for Reinforced Concrete to IS 456-1978:***
   This handbook explains the use of formulae mentioned in IS 456 and provides several design charts and interaction diagrams for flexure, deflection control criteria, axial compression, compression with bending and tension with bending for rectangular cross-sections (for circular section in case of compression member) which can greatly expedite the design process if done manually. This design aid is particularly useful for the preliminary design.

2. **SP 22: *Explanatory Handbook on Codes for Earthquake Engineering (IS 1893: 1975 and IS 4326: 1976):***
   The theoretical background behind many of the code provisions have been elaborated herein. Additionally, many worked out examples explaining the use of equations and charts in the code can also be found in this handbook.

3. **SP 24: *Explanatory Handbook on Indian Standard Code of Practice for Plain and Reinforced Concrete IS 456: 1978***
   SP 16 is meant to aid the calculation process, while SP 24 is meant to aid the conceptual understanding of the IS 456 code. It contains clause by clause explanation of the original code. The logic and justification behind the various equations and assumptions in the code are well explained here.

4. **SP 34: *Handbook on Concrete Reinforcement and Detailing*:**
   The compilation of provisions and guidelines regarding reinforcement detailing scattered throughout IS codes 456, 4326, 5525 and 13920 can be found in this handbook. Searching for that information in the original codes can be very time consuming. This handbook presents all that information in a well-organized manner.

IV. Textbooks on RCC Design and Earthquake Engineering:

Many available books related to design of reinforced concrete structure and earthquake engineering written by distinguished authors such as Pillai and Menon, SN Sinha and AK Jain are based on the Indian Standard Codes of Practice and provides sufficient theoretical background with illustrative examples. So, for the analysis and design, reference from such textbooks are very helpful. Books related to foundation engineering will also be valuable in the design of building foundation. Besides these, other books related to structural mechanics (Statics and Dynamics) will also be helpful for performing and verifying the analysis output from computer software.

Apart from these references there may requires data related to the past earthquake, the earthquake zoning map and soil condition of the site. These data may be obtained from the government authorities and other concerning organizations.

The reports on the same project prepared by the students of previous batches was also an important reference to the project.

Methodology

Nepal is dominated by the Himalaya – the highest, youngest and seismically very active mountain range. Hence building construction in Nepal should consider the seismic loading. In Nepal, design of buildings is mainly based upon the guidelines provided by the Nepal National Building Codes: 000- 1994. But in most of the cases NBC refers to the Indian Standard Building Codes and other foreign building codes and permit the use of such codes. The design based on the foreign codes must fulfill the requirement that the finished structure must meet or exceed both qualitatively and quantitatively the requirements of NBC:000-1994. Hence for this project, analysis and design of the given building is aimed to be done using Indian Standard Codes of Practice and design aids (Special Publications of Bureau of Indian Standard) which follows the limit state design method.

Limit state design (LSD) is also known as Load and Resistance factor Design. Limit state is a condition of a structure beyond which it no longer fulfills the design criteria. The objective of design based on the limit state concept is to achieve and acceptable probability that a structure will not become unserviceable in its lifetime for the use for which it is intended i.e. structure will not reach limit state within its lifetime. The limit state that concern with the safety of people and safety of structure is known as limit state of collapse. It includes the loss of equilibrium of structure, failure by excessive deformation, fatigue, rupture, loss of stability of the structure or any part of it including supports and foundations. The limit state that concern with the functioning of the structure or structural members under normal use, or comfort of people or appearance of the construction works is classified as limit state of serviceability.

The analysis and design of the building in this project will be carried out following the below listed methods:

i. The design and analysis process requires knowledge of structural mechanics and design theories which were acquired in previous semesters (1^{st} to 6^{th} semesters). Reinforced Concrete Design and Earthquake resistant design are being studied in this semester (7^{th} semester). It is planned to learn structural analysis and design software (SAP 2000) during this Semester (7^{th} Semester).

ii. After completing these basic requirements, detailed design of the structure will be accomplished according to the following steps:

- The provided architectural drawing of the apartment building is studied, analyzed and required modifications are made to make the economic seismic resistant design as per the guidance of Supervisor.

- Estimation and idealization of the loads i.e. dead load and live load will be done based on the Indian Standard Code of Practice IS:875-1987 (Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Part 1, 2 and 3).

- Estimation of the seismic load will be based on IS:1993-2002 (Criteria for Earthquake Resistant Design of Structures, Part 1). For Kathmandu Valley, Seismic zone is considered as Zone V and medium (II) soil type. For the detailing of the designed reinforcement IS:13920-1993 (Ductile Detailing for Reinforced Concrete Structures Subjected to Seismic Forces- Code of Practice) will be referred

- After the estimation of probable loads, preliminary design will be done to determine the approximate shape and size of structural members from deflection control criteria provided in codes for beams, slabs and taking load from tributary area in case of column. Thus provided size may be changed after complete structural analysis.

- Modeling of the structure will be done using the software SAP2000 which is published by American software company *Computers and Structures.* This software is freely available for academic purpose.

- Analysis of the structure will also be carried out using SAP2000 which analyses the structure based on the Finite Element Method. The results of design obtained from SAP2000 will be also verified using other software packages.

- All the calculations for the design will be based on IS:456-2000 (Plain and Reinforced Concrete- Code of Practice), IS:4326-2003 (Earthquake Resistant Design and Construction of Buildings- Code of Practice), IS:5525-1999 (Recommendations for Detailing of Reinforcement in Reinforced Concrete Works) and IS:13920-1993. Beside these codes design aids Indian Standard Special Publications (SP 16, SP 22, SP 24 and SP 34) along with the textbooks by Pillai and Menon, SN Sinha, AK Jain etc. will be referred.

- Final outcome of the analysis and design will be the structural drawing including detail ductile detailing of the reinforcement bars based on IS 13920 and other related Indian Standard codes.

- If sufficient time is left at the end, estimation of cost for the construction of the building will also be carried out.

- After the complete analysis and design, required modifications for the provided architectural drawing including size of structural members, partition walls etc. will be carried out and all the drawing will be printed in appropriate format for inclusion with the final report.

Time Schedule

The project has been allocated to the completed in the time being of 7th and 8th semester of Civil Engineering. The first phase of the project which includes the theoretical study of RCC design, documents related to seismic design and codes, architectural corrections needed in the drawing and preliminary design of the structure has been completed during the 7th semester. Also, a proposal for the project is submitted.

Presently, the following tasks have been completed.

Task	Time Duration
Group Formation	5-Dec-16 to 10-Dec-16
Project Selection	10-Dec-2016 to 21-Dec-16
Interaction with Supervisor	21-Dec-16 to 22-Dec-16
Group Interaction	22-Dec-16 to 25-Dec-16
Project Briefing	25-Dec-16 to 26-Dec-16
Project Title and Objective Confirmation	27-Dec-16 to 29-Dec-16
Pre-proposal Preparation	29-Dec-16 to 31-Dec-16
Pre-proposal Submission	1-Jan-17 to 1-Jan-17
Literature Review	2-Jan-17 to 18-Jan-17
SAP Study	18-Jan-17 to 6-Feb-17
Drawing received and Discussion	23-Feb-17 to 6-Mar-17
Presentation by Supervisor	6-Mar-17 to 6-Mar-17
Completion of Proposal	7-Mar-17 to 9-Mar-17
Preliminary Design Work	7-Mar-17 to 16-Mar-17

Future Works

The second phase of the project will have begun before the start of the 8th semester. The second phase of the project will be comprised of the following tasks:

- Idealization of structure
- Load assessment
- Modeling and Analysis of structure
- Design
- Drawing and Detailing
- Estimating and Costing