EXPERIMENTAL ANALYSIS OF EARTHQUAKE RESISTANT AND DESIGN OF MULTISTOREYED RESIDENTIAL BUILDING

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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 is commenced within the above-mentioned criteria. Also, the strength and serviceability criteria are fulfilled. The final output of the project is object in the form of detailed drawings.

1.1. Introduction

Humans have a fundamental desire for a safe place to live. The definition of a shelter is a place that provides temporary refuge from dangerous weather or other threats. Temporary dwellings, such as caves, provided enough housing for early humans. They eventually constructed makeshift homes out of trees and bushes. As our species progressed, we began constructing more permanent dwellings out of masonry elements such as mud, stones, timber, straw, dongs, and the like. However, these early dwellings lacked structural integrity. As time progressed and new building techniques emerged, humans began to construct increasingly sturdy and long-lasting dwellings.

Constructing dwellings alone is insufficient in the current setting. Even though the population is growing at a rapid pace, there is less land available for building. Additionally, the cost of land in Nepal's capital is so high that even a small family cannot afford to build a home there. Building vertically rather than laterally is necessary due to the scarcity and exorbitant cost of available land. As a result, most of the new buildings in Kathmandu are very tall and feature multiple stories.

A further consideration in structural design is the impact of the recent Gorkha earthquake, which happened on April 25, 2015, at 11:56:26 NST. An intense earthquake of 7.8 Richter occurred, with a focal point 8.2 km below ground and a Mercalli intensity of rating IX. There were an estimated 23,447 wounded and 8,959 fatalities, resulting in a total estimated loss of $5 billion. Across the nation, the destruction of entire communities caused hundreds of thousands of people to lose their homes. Seismic design and analysis of multi-story buildings are now more widely known as a result of the earthquake's increased public awareness of the unique loading patterns, subterranean carrying capacity, and other factors, such as wind and storey drift.

1.2. Literature Review

Prior knowledge and data are the foundation upon which every engineering design rests. Verifying analytical and design outcomes against preexisting standards or best practices is critical. When designing a structure, it is important to consider its rigidity, strength, and stability in a methodical way. Structural analysis and design primarily aim to build structures that can bear all loads for their entire service life without collapsing. Integrating knowledge of structural mechanics with insights from the past allows us to create safe design approaches. Providing reputable references for the designs is essential to ensure adherence to construction codes. Furthermore, these rules protect designers in the event that the structure fails within the specified lifespan. The following literature outlines the specific references and criteria for this design.

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

In 1993, a thorough effort to lessen the effects of earthquakes on Nepal's buildings led to the establishment of the Nepal National Building Code. Building strength, site considerations, construction safety, and fire dangers are the primary areas of emphasis in this code. Through the provision of standards and mandatory laws, it seeks to standardize building methods. The lack of many necessary supporting documents is a result of its recent inception, nevertheless, and to make up for this, it frequently refers to Indian Standard codes. The National Building Code identifies four tiers of complexity in building design and construction.

I. Cutting-edge technology on a global scale ii. Buildings designed and constructed by experts

iii) Small structures are planned using basic principles.

iv. Rural and out-of-the-way structures for which control is not feasible

This project falls under the second NBC category of professionally engineered structures.

II. Indian Standard Codes of Practice

The National Building Codes of Nepal, which frequently refer to Indian Standard codes, provide insufficient information, so we have made references to these codes for the building's analysis and design. The following Indian Standard codes have been applied in this project:

- This section defines the dead loads assumed in the building design, providing unit weights for various materials and components.

- **Part 2: Imposed Loads**
  This part addresses loads from intended use or occupancy, including moveable partitions and other dynamic loads, while excluding certain factors like wind and seismic loads.

Typical Floor (2nd to 10th Floor) vs. Basement

Element	Mass (kN)	Mx (kNm)	My (kNm)		Element	Mass (kN)	Mx (kNm)	My (kNm)
Column n	840.105	8802.20	10361.45		Column n	856.6916	8975.987	10566.02
Beam	1081.564	11332.03	13061.74		Beam	1081.564	11332.03	13061.74
Slab	1320.198	14164.33	15692.99		Slab	1677.274	17578.21	20011.07
Wall	2273.315	23818.66	27582.92		Wall	1057.812	11083.23	12493.82
Total	**5515.182**	**58117.22**	**66699.09**		**Total**	**4673.342**	**48969.45**	**56132.65**

Center of Mass

	Along X-axis (m)	Along Y-axis (m)
Typical Floor	10.53768	12.09372
Basement	10.47847	12.01124

Center of Rigidity

	Along X-axis (m)	Along Y-axis (m)
Typical Floor	10.4775	12.33351
Basement	10.4775	12.33351

1st Floor vs. Staircase Cover

Element	Mass (kN)	Mx (kNm)	My (kNm)		Element	Mass (kN)	Mx (kNm)	My (kNm)
Column	979.8985	10266.89	12085.59		Column	144.78	1516.932	1550.029
Beam	1081.564	11332.03	13061.74		Beam	180.0135	1886.059	1927.207
Slab	1320.198	15692.99	15692.99		Slab	259.2648	2716.447	2775.715
Wall	2273.315	23818.66	27582.92		Wall	296.2482	3103.940	3171.663
Total	**5654.976**	**61110.57**	**68423.24**		**Total**	**880.3065**	**9223.379**	**9424.613**

Center of Mass

	Along X-axis (m)	Along Y-axis (m)
1st Floor	10.80651	12.09965
Staircase Cover	10.47746	10.70606

Center of Rigidity

	Along X-axis (m)	Along Y-axis (m)
1st Floor	10.4775	12.33351
Staircase Cover	10.4775	10.7061

Eccentricity Calculation

Element	Along X-axis	Along Y-axis
Typical Floor (2nd to 10th floor)	0.060179219	0.239789832
1st Floor	0.329013114	0.233862113
Basement	0.000966114	0.322269666
Staircase Cover	0	0

Basement Properties

Parameter	Value
Height (h)	2.798 m
Width (b)	0.54 m
Depth (d)	0.54 m
Modulus of Elasticity (E)	25,000,000 kN/m^2
Moment of Inertia (I)	0.007086 m^4
Stiffness (K)	97,044.72 kN/m

S.N.	Grid	K (kN/m)	x (m)	y (m)	kx (kN/m)	ky (kN/m)
1	A1	97044.721	0.000	0.000	0.000	0.000
2	B1	97044.721	3.277	0.000	317976.724	0.000
3	C1	97044.721	8.306	0.000	806034.021	0.000
4	D1	97044.721	12.649	0.000	1227538.050	0.000
5	E1	97044.721	17.678	0.000	1715595.348	0.000
6	F1	97044.721	20.955	0.000	2033572.071	0.000
7	A2	97044.721	0.000	3.962	0.000	384529.992
8	B2	97044.721	3.277	3.962	317976.724	384529.992
9	C2	97044.721	8.306	3.962	806034.021	384529.992
10	D2	97044.721	12.649	3.962	1227538.050	384529.992
11	E2	97044.721	17.678	3.962	1715595.348	384529.992
12	F2	97044.721	20.955	3.962	2033572.071	384529.992
13	A3	97044.721	0.000	8.306	0.000	806034.021
14	B3	97044.721	3.277	8.306	317976.724	806034.021
15	C3	97044.721	8.306	8.306	806034.021	806034.021
16	D3	97044.721	12.649	8.306	1227538.050	806034.021
17	E3	97044.721	17.678	8.306	1715595.348	806034.021
18	F3	97044.721	20.955	8.306	2033572.071	806034.021
19	A4	97044.721	0.000	13.106	0.000	1271906.896
20	B4	97044.721	3.277	13.106	317976.724	1271906.896
21	C4	97044.721	8.306	13.106	806034.021	1271906.896
22	D4	97044.721	12.649	13.106	1227538.050	1271906.896
23	E4	97044.721	17.678	13.106	1715595.348	1271906.896

24	F4	97044.721	20.955	13.106	2033572.071	1271906.896
25	A5	97044.721	0.000	16.993	0.000	1649042.080
26	B5	97044.721	3.277	16.993	317976.724	1649042.080
27	C5	97044.721	8.306	16.993	806034.021	1649042.080
28	D5	97044.721	12.649	16.993	1227538.050	1649042.080
29	E5	97044.721	17.678	16.993	1715595.348	1649042.080
30	F5	97044.721	20.955	16.993	2033572.071	1649042.080
31	A6	97044.721	0.000	20.345	0.000	1974413.611
32	B6	97044.721	3.277	20.345	317976.724	1974413.611
33	C6	97044.721	8.306	20.345	806034.021	1974413.611
34	D6	97044.721	12.649	20.345	1227538.050	1974413.611
35	E6	97044.721	17.678	20.345	1715595.348	1974413.611
36	F6	97044.721	20.955	20.345	2033572.071	1974413.611
37	A7	97044.721	0.000	23.622	0.000	2292390.335
38	B7	97044.721	3.277	23.622	317976.724	2292390.335
39	C7	97044.721	8.306	23.622	806034.021	2292390.335
40	D7	97044.721	12.649	23.622	1227538.050	2292390.335
41	E7	97044.721	17.678	23.622	1715595.348	2292390.335
42	F7	97044.721	20.955	23.622	2033572.071	2292390.335

Summary

- **Total K:** 4,075,878.298 kN/m
- **Total kx:** 42,705,013.501 kN/m
- **Total ky:** 50,269,901.607 kN/m

Center of Stiffness

- **X-axis:** 10.477 m
- **Y-axis:** 12.334 m

1st Floor Stiffness Data

- Height (h): 3.2004 m
- Width (b): 0.54 m
- Depth (d): 0.54 m

- Modulus of Elasticity (E): 25,000,000 kN/m²
- Moment of Inertia (I): 0.007086 m⁴
- Stiffness (K): 64,848.85 kN/m

S.N.	Grid	Stiffness K (kN/m)	x (m)	y (m)	kx (kN/m)	ky (kN/m)
1	A1	64848.848	0.000	0.000	0.000	0.000
2	B1	64848.848	3.277	0.000	212483.727	0.000
3	C1	64848.848	8.306	0.000	538621.541	0.000
4	D1	64848.848	12.649	0.000	820286.017	0.000
5	E1	64848.848	17.678	0.000	1146423.831	0.000
6	F1	64848.848	20.955	0.000	1358907.558	0.000
7	A2	64848.848	0.000	3.962	0.000	256957.065
8	B2	64848.848	3.277	3.962	212483.727	256957.065
9	C2	64848.848	8.306	3.962	538621.541	256957.065
10	D2	64848.848	12.649	3.962	820286.017	256957.065
11	E2	64848.848	17.678	3.962	1146423.831	256957.065
24	F4	64848.848	20.955	13.106	1358907.558	849934.909
25	A5	64848.848	0.000	16.993	0.000	1101950.492
26	B5	64848.848	3.277	16.993	212483.727	1101950.492
27	C5	64848.848	8.306	16.993	538621.541	1101950.492
28	D5	64848.848	12.649	16.993	820286.017	1101950.492
29	E5	64848.848	17.678	16.993	1146423.831	1101950.492
30	F5	64848.848	20.955	16.993	1358907.558	1101950.492
31	A6	64848.848	0.000	20.345	0.000	1319375.701
32	B6	64848.848	3.277	20.345	212483.727	1319375.701
33	C6	64848.848	8.306	20.345	538621.541	1319375.701
34	D6	64848.848	12.649	20.345	820286.017	1319375.701
35	E6	64848.848	17.678	20.345	1146423.831	1319375.701
36	F6	64848.848	20.955	20.345	1358907.558	1319375.701
37	A7	64848.848	0.000	23.622	0.000	1531859.429
38	B7	64848.848	3.277	23.622	212483.727	1531859.429
39	C7	64848.848	8.306	23.622	538621.541	1531859.429
40	D7	64848.848	12.649	23.622	820286.017	1531859.429
41	E7	64848.848	17.678	23.622	1146423.831	1531859.429
42	F7	64848.848	20.955	23.622	1358907.558	1531859.429

Summary

- **Total Stiffness K:** 2,723,651.60 kN/m
- **Total kx:** 28,537,058.71 kN/m
- **Total ky:** 33,592,194.83 kN/m

Center of Stiffness

- **X-axis:** 10.477 m
- **Y-axis:** 12.334 m

An Introduction to Base Shear Analysis. In accordance with Clause 6.4.2 of IS 1893 (Part I), we compute the horizontal seismic coefficient for construction using the following formula:

$$A_h = \frac{Z \cdot I \cdot S_a}{R \cdot g}$$

Where:

- Z = Zone factor from IS 1893 (Part I): 2002, Table 2. For Zone V, $Z = 0.36$.
- I = Importance factor, which is $I = 1$ for general purpose buildings.
- R = Response reduction factor from IS 1893 (Part I): 2002, Table 7. Here, $R = 5.0$.
- S_a = Average response acceleration coefficient based on the approximate fundamental natural period of vibration T_a.

For $T_a = 1.4$ seconds and soil type III (Soft Soil), $S_a = 0.97\,g$.

Thus, the design horizontal seismic coefficient can be calculated as:

$$A_h = \frac{0.36 \cdot 1 \cdot 0.97}{2 \cdot 5} = 0.03497$$

According to Clause 7.5.3 of IS 1893 (Part I): 2002, the total design lateral force (base shear) V_B along any principal direction is given by:

$$V_B = A_h \cdot W$$

Where W is the seismic weight of the building, which is $W = 70386.51\,\text{kN}$.

Therefore, the base shear V_B is calculated as:

$$V_B = 0.03497 \cdot 70386.51 = 2461.416\,\text{kN}$$

Floor	W_i (KN)	H_i (m)	$W_i \cdot H_i^2$	Q_i (KN)	V_i (KN)	Calculated x	Calculated y	Permissible x	Permissible y	Torsion Check x	Torsion Check y
Terrace (C over)	991.67	37.70	1,409,276.88	106.16	106.16	0.00	0.00	4.19	4.72	ok	ok
10	5664.23	34.80	6,860,403.48	516.80	622.96	0.06	0.24	4.19	4.72	ok	ok
9	6417.17	31.60	6,408,573.82	482.76	1,105.72	0.06	0.24	4.19	4.72	ok	ok
8	6417.17	28.40	5,176,266.50	389.93	1,495.65	0.06	0.24	4.19	4.72	ok	ok
7	6417.17	25.20	4,075,415.60	307.00	1,802.66	0.06	0.24	4.19	4.72	ok	ok
6	6417.17	22.00	3,106,021.10	233.98	2,036.63	0.06	0.24	4.19	4.72	ok	ok
5	6417.17	18.80	2,268,083.02	170.86	2,207.49	0.06	0.24	4.19	4.72	ok	ok
4	6417.17	15.60	1,561,601.34	117.64	2,325.13	0.06	0.24	4.19	4.72	ok	ok
3	6417.17	12.40	986,576.07	74.32	2,399.45	0.06	0.24	4.19	4.72	ok	ok
2	6417.17	9.20	543,007.22	40.9	2,440.35	0.06	0.24	4.19	4.72	ok	ok
1	6487.06	6.00	233,409.71	17.58	2,457.93	0.33	0.23	4.19	4.72	ok	ok
Basement	5906.21	2.80	46,238.59	3.48	2,461.42	0.00	0.32	4.19	4.72	ok	ok
Total	70,386.51		32,674,873.34	2,461.42							

Notes

- The data represents various parameters related to the analysis of each floor in a building, including dead loads, heights, moments of inertia, and torsion checks.
- All values meet the permissible limits for torsion checks.
- The total seismic weight of the building is **70,386.51 KN** and the calculated base shear is **2,461.42 KN**.

CalculationofStoreyDrift

WhenearthquakeinactionalongX axis

Floor Level	Floor Height (m)	Node ID	Absolute Displacement (m)	Relative Displacement (m)	Permissible Displacement (m)	Remark
11 (Terrace)	2.8956	85	0.0455	0.001	0.0115824	ok
10	3.2004	524	0.0445	0.0019	0.0128016	ok
9	3.2004	482	0.0426	0.0028	0.0128016	ok
8	3.2004	440	0.0398	0.0036	0.0128016	ok
7	3.2004	398	0.0362	0.0043	0.0128016	ok
6	3.2004	356	0.0319	0.0048	0.0128016	ok
5	3.2004	314	0.0271	0.005	0.0128016	ok
4	3.2004	272	0.0221	0.0053	0.0128016	ok
3	3.2004	230	0.0168	0.0053	0.0128016	ok
2	3.2004	188	0.0115	0.0052	0.0128016	ok
1	3.2004	146	0.0063	0.0043	0.0128016	ok
Ground	2.798	20	0.002	0.002	0.011192	ok
Basement	0	62	0	0	0	ok

WhenearthquakeinactionalongY-axis

Floor Level	Floor Height (m)	Node ID	Absolute Displacement (m)	Relative Displacement (m)	Permissible Displacement (m)	Remark
11 (Terrace)	2.8956	89	0.0436	0.0008	0.0115824	ok
10	3.2004	521	0.0428	0.0016	0.0128016	ok
9	3.2004	479	0.0412	0.0026	0.0128016	ok
8	3.2004	437	0.0386	0.0033	0.0128016	ok
7	3.2004	395	0.0353	0.0041	0.0128016	ok
6	3.2004	353	0.0312	0.0045	0.0128016	ok
5	3.2004	331	0.0267	0.0049	0.0128016	ok
4	3.2004	269	0.0218	0.0052	0.0128016	ok
3	3.2004	227	0.0166	0.0052	0.0128016	ok
2	3.2004	185	0.0114	0.0051	0.0128016	ok
1	3.2004	143	0.0063	0.0043	0.0128016	ok
Ground	2.798	17	0.002	0.002	0.011192	ok
Basement	0	59	0	0	0	ok

6. DesignandDetailing

6.1 Slab Design:

Slabs are plate pieces that flex to distribute loads, composing building floors and roofs. Another way to categorize slabs is by whether they are simply supported or continuous over several supports.

(a) A slab that spans both ways in one direction.

(b)The cross-sectional slab is designed to span in both directions.

(c) slabs that are round

(d) Slabs that are flat onto a column

(e) A ribbed slab with a grid floor

We also use the beam's bending and shear theories to build the slab.

(a) Analysis of elasticity (strip idealization as a beam)

b) The coefficients are approaching empirical values, as specified in the code.

(c) The theory of yield lines

Slabs, beams, and columns all receive reinforcement, although slabs receive the least amount of it. Here are several ways to tell a slab apart from a beam:

(a) The slab's minimum span must be at least four times depth.

When designing the slab, we consider and account for a unit width of 1 meter.

We never use compressional reinforcement.

(d) Slabs do not require shear reinforcement because the shear stress is minimal. If necessary, we increase the depth instead of applying shear reinforcement.

The detailed design selected a single long-span corridor slab capable of withstanding a live load intensity of 3 kN/m2. Below is a detailed view of the slab and its underlying beams.

The beam's depth is 500 millimeters. The beam's width is 300 micrometers.

Slab depth of 150 mm is assumed.

With Lx = 4043.5 mm and Ly = 4500.7 mm, the chosen Slab panel's measurements are straightforward.

8. Corner Reinforcement:

- Additional reinforcement at corners provided based on 75% of the total area of main reinforcement.

Conclusion:

The design meets the requirements for structural safety, stability, and serviceability as per IS 456:2000. The specified reinforcement sizes, spacing, and details ensure the slab will perform adequately under the specified loads, while also addressing deflection and shear concerns.

6.2 Designof Beams

Beams are structural components designed to transfer loads from the slab to the columns. In these members, flexural stress is typically more significant than shear stress.

Reinforced concrete beams come in three varieties:

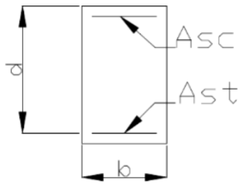
1. Beams with only one reinforcement
2. Reinforced beams with two layers.
3. Flanged beams with reinforcement, either single or double

Reinforcement is present in the tension and compression regions of doubly reinforced concrete beams. If the sectional depth is constrained for practical or aesthetic reasons, steel must be used in the compression area. Considerations for serviceability limit states like deflection, crack width, and durability are part of a thorough beam design that also accounts for safety under ultimate limit states including flexure, shear, torsion, and bond. There are primarily two steps to the design process: section analysis and section design.

The analytical phase involves using the cross-section and reinforcing details to find the moment of resistance.

M25 is the concrete grade.

Chemical No.: Fe500



7. Conclusion

Building structures in Nepal requires careful consideration of the country's tectonically active zone to ensure their safety, durability, and functionality. There are unique hazards and difficulties brought about by this geological setting that engineers must carefully consider. We, the undersigned Civil Engineering students, are extremely grateful to our respected advisor and the hardworking faculty members who have helped us grow professionally. Their advice has been crucial in developing our grasp of these fundamental concepts. It is our deepest wish that this initiative lives up to the lofty expectations they have placed in us and beyond them.

8. References

8.1 CodeofPracticeandSpecialPublications

1. "sf7df8f}}pkTosfleqsfgu/kflnsf/gu/f]Gd[vuflj;x?dful/g]lgdf{0f;DaGwLdfkb08-@)^$",g]kfn ;/sf/,eflTsof]hgftyflgdf{0fdGqfno,sf7df8f}}pkTosfgu/las f;;ldlt,cgfdgu/.
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