Recapturing Nepal National Library: A Contemporary Earthquake Resistance Solution to a Traditional Architecture

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Abstract

The sheer magnitude of 7.8 Richter scale 2015 Gorkha earthquake witnessed millions of property damage and loss those including private houses, public buildings namely schools, libraries, hospitals, health centers and archeological heritages and so the damage of Neo-classical Rana palace Harihar Bhawan located at Pulchowk as well. Built in 1925 by Chandra Shamsher Jang Bahadur Rana, it housed one of the country’s historically remarkable library Nepal National Library (NNL) since 1961. More than 150,000 books of all genres and of different languages were at risk of deterioration. On its struggle to be destined at a safer and permanent location, Government of Nepal, Ministry of Education, Science and Technology has programmed to reconstruct new National Library depicting Nepali tradition, culture, lifestyle and architecture with priority given to seismic design and earthquake resistant building system at 4067.85 square meter of land at Jamal, Kathmandu. It is not the earthquake which kills the people but it is the unsafe buildings which is responsible for the wide spread devastation. The present paper outlines the vulnerability in terms of its seismic performance of historic Neo-classical building currently housing NNL and that of faulty construction practice of common Reinforced Concrete building and thereby proposes a contemporary Earthquake Resistant R.C.C frame structural system according to the relevant National and International Building Code for new Nepal National Library while echoing the distinctive traditional architectural style of Kathmandu Valley as an attempt to promote cultural conservation and traditional wisdom.

Key words: earthquake, Neo-classical, vulnerability, architecture, earthquake resistant R.C.C frame structure, traditional, contemporary

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1. Introduction

In April 2015, a tectonic earthquake of 7.8 Richter hit Barpak, Gorkha causing several damages in many regions of Nepal. Harihar Bhawan- A Neo-classical European style of architecture-which lies in Lalitpur was partially damaged during the April 2015 Nepal earthquake. Harihar Bhawan was designated unsafe and received a red sticker. Currently the Department of Agriculture, National Library of Nepal and National Human Rights Commission has started evacuation. The future of this Historical building is unknown (Rana palaces after the earthquake, 2015). Most of the traditional buildings in Nepal were constructed in mud mortar, and later some of the prestigious buildings in lime surkhi mortar. Brick masonry is still one of the most popular construction materials with cement sand mortar. Due to the low tensile strength of masonry both the newer and older masonry building are highly vulnerable to the earthquake. In general, the old traditional buildings are low-rise, and most of them have been constructed for residential purposes. These traditional buildings consist of timber floors. The seismic assessment of such buildings is very essential for the conservation and for upgrading their performance for future earthquake (Khadka, 2013). Like most of the neoclassical palaces built in those time, Harihar Bhawan, an unreinforced masonry, was built using the best available materials during the time but their seismic resistance was intrinsically limited since no building codes were available back then. Also, the advanced construction materials like concrete and steel were not easily available and it was made based upon the traditional expertise and technology.

It has been reported that the Neo-classical Harihar Bhawan was converted to Library in 1961. The National Library, part of the Harihar Bhawan complex that houses several government offices, was given a red sticker after the earthquakes, meaning it had been damaged beyond repair and is dangerously unstable. Following this designation, the National Library, which is Nepal’s first public library, moved to a small corner of Harihar Bhawan. The Nepal National Library, which has over 150,000 books of all genres, now hosts about 12,000 children’s books in its new location while the rest of its books are now in storage. (Sijapati, 2019). A meeting held at the NHRC premises on 5 May, 2015 suggested the Government of Nepal to immediately dismantle the damage buildings at Harihar Bhawan and rebuild them at the same location since these damaged buildings cannot be protected any longer.

The reason for the fragile state of this building according the findings are continuous deterioration due to weather which left this URM vulnerable during seismic force, no repair and maintenance for a long period of time which deteriorated the building and brittle failure which is caused in the load bearing structures. As per the decision made in 2018, the government had decided to construct a new library building structure for NNL at Jamal, Kathmandu for its permanent location after struggling to find land to rehabilitate this institution. The government has programmed to construct National Library depicting Nepali tradition, culture, lifestyle and architecture.

A national library is a library established by a government as a country's preeminent repository of information. Often, they include numerous rare, valuable, or significant works. A national library is that library which has the duty of collecting and preserving the literature of the nation within and outside the country. Thus, national libraries are those libraries whose community is the nation at large. Examples include the British Library, and the Bibliothèque nationale de France in Paris (Line, 2011). With this consideration, an attempt has been made to make the building not only aesthetically appealing to the eye revealing rich culture, tradition and architecture of our country but also functionally and structurally faultless.
2. Methodology

Qualitative assessment of the Harihar Bhawan was undertaken based on the visual observation at site, review of available documents and similar studies are taken into account for the structural damage and functional damage to the building. In addition information was gathered from interviews with those who were involved in the NNL.

Design features and considerations are incorporated as guidelines for the architectural design of this prestigious library. Architectural plans, elevation and cross-sectional elevations are prepared abiding by the existing bylaws and National and International Building Codes in AutoCad-2017 model. 3D model of the building is prepared using SKETCHUP 18 and LUMION. The seismic structural design is found to be very essential for countries like Nepal. Building structures are designed and detailed to counteract the internal forces induced due to the earth mass shaking. The design should ensure the structure against stability, strength and serviceability with acceptable levels of seismic safety. In general context of Nepal, the building is located in seismic zone V and the soil type III. Seismic Analysis has been based on Code. The building is designed in accordance with Indian Standard Code for load calculation, structural analysis and design.

An in-depth knowledge of site-specific geological and geotechnical engineering is essential for design and construction of almost all infrastructure components, including earthquake-resistant buildings. The Himalaya range being one of the world’s most seismically active areas on earth and since Nepal occupies nearly one-third of the range, the Geotechnical study is must before commencing foundation design of the major structure. The seismic motion that reaches a structure on the surface of the earth is influenced by local soil conditions. The subsurface soil layers underlying the building foundation may amplify the response of the building to earthquake motions originating in the bedrock. For soft soils the earthquake vibrations can be significantly amplified and hence the shaking of structures on soft soils can be much greater than for structures on hard soils. The very loose sands or sensitive clays would result in large unequal settlements and damage the building. If the loose cohesion less soils are saturated with water they are likely to lose their shear resistance altogether during ground shaking thereby leading to liquefaction. Hence, appropriate soil investigation has been carried out to establish the allowable bearing capacity and nature of the soil.

3. Result

3.1 Outline of Structural Deficiencies of the Historic Building Harihar Bhawan

Nepal experienced a new scenario in construction of buildings during the middle of the Nineteenth century. After returning from the Europe tour the first Rana Prime Minister Janga Bhadur Rana built the palaces for him with inspiration of the European style. Construction of such neo-classical building introduced in 1850 AD continued to take place during over 100 years of ruling by Rana family. These palaces of neo-classical type are scattered all over the Kathmandu valley. It is to be noted that these places were used for residential purpose in general, and the construction was different from that of other civil residential buildings in terms of quality and grandiose. These palaces are usually three storied and cover large area with huge compounds. The large wings of the buildings are of gallery type with long corridors with spacious rooms of different sizes (Khadka, 2013). The total number of the fully damaged buildings as a result of the Gorkha earthquake was determined to be 498,852, with the number of partially damaged buildings being 256,697. Among them, low-strength masonry buildings accounted for 95% of the fully damaged building (474,025) and 67.7% of the partially damaged buildings (173,867). In contrast, cement-based masonry buildings accounted for 3.7% of the fully damaged buildings (18,214) and 25.6% of the partially damaged buildings (65,859). The
remainder was reinforced concrete buildings. (National Planning Commission, 2015). This shows the significant contribution of masonry structure against the disastrous damage during the past earthquake. Harihar Bhawan was constructed with thick URM walls in lime mortar and timber floors. URM structures are vulnerable to collapse in an earthquake. One problem is that most mortar used to hold bricks together is not strong enough. (Earthquake Country Alliance, 2020). Earthquake Country Alliance. Most of those older masonry buildings are designed primarily to resist gravity loads only since the provision for earthquake loading codes were not then established. It was observed in frequent earthquakes that older masonry structures perform poorly and most of those buildings would collapse in a major earthquake. The clay brick material is relatively heavy, brittle, of low tensile strength and show low ductility when subjected to seismic excitation (Wijanto, 2007).

A number of common failures of URM buildings have been observed from around the world. Bruneau (1994), regrouped the failure performances as follows: lack of anchorage, anchor failure, in-plane failures, out-of-plane failure, combined in-plane and out-of-plane effects and diaphragm-related failures. Many older URM-buildings lack positive anchorage of the floors and roof to the URM-walls, which contribute to sudden failure under seismic excitation. Anchor failure depends on the material properties which are unsuitable to seismic resistance. The in-plane failure characterized by a shear crack pattern, where cracks are primarily along the mortar bed joints; some inclined cracks may also be developed. The exact crack pattern will, of course, depend on the wall boundary conditions and the aspect ratio of the URM elements. Seismic actions are bidirectional and the URM can perform in both in-plane and out-of-plane direction. Improperly anchorage of floor/roof diaphragms to the URM walls and out-of-plane failure can cause failure of the diaphragm transfer the horizontal seismic forces. The out-of-plane failure has been identified as the major cause of loss of life during the earthquakes. From previous earthquake experience showing the vulnerability of URM buildings, the current regulations for construction and design in seismic prone areas throughout the world no longer recommend the use of unreinforced masonry structures. Considerable attention to the means of evaluation and strengthening of the all older masonry buildings that exists in seismic prone area is necessary. Most of the unreinforced masonry research is focused on the performance of existing rather than new structures (Wijanto, 2007).

From visual investigation some other deficiencies leading to the vulnerability of the Harihar Bhawan during earthquake has been identified. Building was constructed without the damp proof course with load bearing thick walls in lime mortar and stucco plastered. Besides well burnt bricks some quantity of sun dried bricks are also used for cavity fillings. Foundations contracted mostly of the bricks bearing on the native soil and comprising stepped brick walls. The shape of the room being relatively long and rectangular greater than 10m without buttress walls supporting the unsupported wall length. Also, they lacked vertical reinforcement in the walls, corners and junctions. As per the investigation, it was found that it lacked positive anchorage of floor and roof to the walls. Lack of horizontal bands, corner-stitch, and gable bands in the structure also proved crucial during the earthquake as it made them more vulnerable to earthquake.
3.2 Outline of Common Structural Deficiencies with Reinforced Concrete Building in Practice

Reinforced cement concrete (R.C.C) construction has been the most common type of building and infrastructure construction in our country for nearly 4 decades. R.C.C is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars (rebar) and is usually embedded passively in the concrete before the concrete sets. The load bearing structures undergo a brittle failure, while, a well-built and properly designed Reinforced Cement Concrete or RCC structure undergoes a ductile failure. Additionally, over the last few years, there has been significant progress in the design and construction of seismic-resistant reinforced concrete buildings with the inclusion of earthquake loading in design codes that has facilitated the design engineer to consider the effects of earthquake loading on structures as per its intended use during the design phase. While no structure can be entirely immune to damage from earthquakes, earthquake-resistant R.C.C structures stands far better during seismic activity than their conventional counterparts at their location ensuring that the structures can live through the anticipated...
earthquake exposure up to the expectations, hence resulting zero loss of human life due to collapse of structure.

Heavy damaged to reinforced concrete buildings in Kathmandu were observed in many places such as Gongabu, Balaju, Ramkot, Sitapaila, Manamaiju, Guheshwori, Lakanthali, Syuchatar, Bungamati, Changu Narayan, Chamati etc. The recently constructed RC frame residential building at Ramkot village of Kathmandu was constructed on the black cotton soil as observed in the nearby pits. This three storey building was collapsed by soft-first storey failure mechanism causing pancaking of first two stories. Structural layout of the buildings shows that total number of columns (size 9”x12”) is 16, which are arranged symmetrically in plan area of 1162 sq.ft. The structural layout of the building seems good so far as multiple load path and regular plan is considered. But in the field it is observed that size of stirrups in columns is 6mm spaced at 150 mm c/c and reinforcement detailing was very poor. Also, it is found that when a piece of broken concrete taken out from damaged column was pressed in the palm, it was crushed easily. So the compressive strength of concrete is expected not as much as per requirement. This indicates that presence of weak soil in the foundation, poor workmanship, and lack of ductile detailing are the major factors contributing to the collapse of this building. Similar type of failure mechanism was observed in Chamati, near Bishnumati river. These buildings had opening in the first floor and sizes of the columns were also inadequate. Addition of more stories on the same sized columns was done on both the buildings (Shrestha, 2015).

2015 earthquake has damaged large scale of reinforced concrete buildings as well. Some of the combinations of errors leading to the damages:

- Code imperfections and no use of existing design codes
- Non-engineered construction
- Low Quality of construction
- Low Quality construction materials
- Error in analysis and design while configuring structure system and proportioning of structural elements as per use of building and its seismic performance
- Mass irregularities, poor material quality, faulty construction practice
- Soil and foundation effect: Foundation designed following mandatory rules of thumbs without knowing bearing capacity of soil.
- Pounding of adjacent structure
- Inadequate seismic and ductile detailing in structural component (Column and beam joint problem, Faulty design practice in Lap splice, Transverse reinforcement in column without proper hooks angle
- no good ties existed between the walls and the floors and roofs.
- Building system is moment resisting frame consisting of reinforced concrete slab cast monolithically with beams and columns on shallow footing.
- Infill wall made of unreinforced bricks
- Basement without infill wall creating soft / weak storeys.
- Overhanging balconies or upper floors
- Columns designed for axial /gravity force only without considering effect of lateral force

Hence it is mandatory to do the proper seismic analysis and design to structural against collapse and make the infrastructures we construct today an earthquake resistant in order to mitigate the potential devastation caused by future earthquakes in a most effective way, yet there should be no compromise in building compliance. This has been a lesson learnt
experience to engineers, architects, builders and administrators for improving planning, design analysis, and construction practice and for enforcement and monitoring of design codes.

### 3.3 Architectural Design Features and Considerations for the Proposed NNL Building:

Design features and considerations incorporated as guidelines in proposed design are as follows:
• **Homage to traditional Nepalese Architectural Style**

Traditional Nepalese architecture is renowned for its distinctiveness. Its originality and magnificence is depicted in lavishly carved wooden windows on backgrounds of red brick walls. In the establishment of this proposed NNL building, history is sure to come alive where it has been attempted to incorporate a tasteful mélange of the rich tradition and architecture of Malla Era to create a unique, generous yet functional and contemporary architectonic work as an attempt to revive and promote the original traditional taste that was once used to be the part of our cultural heritage.

• **Adherence to the statutory requirement**

The building has been sited and designed adhering to the standard Building Code….., land use planning, building bye-laws and related statutory requirements to ensure good engineering standards of physical facilities.

• **Siting of the Building**

The siting of the building has been done pensively considering the site as a focal point as how the building could create a dialogue with the other landmark buildings that define the skyline of location and harmonize with the surrounding.

• **Consideration on environmental Impact**

Design has been done with due regard given to its impact on the surrounding natural and built environment such that the design does not harm the existing environment in any way and do not waste its finite resources, moreover, enhance the surrounding environmental values and ensure a healthy living environment. Furthermore, design consideration has been given to the successful integration of all forms of development with the surrounding context.

• **Socio- Cultural value:**

The design has been done to portray the lifestyle, people's ethical belief, its suitability to the social and cultural context, arts, crafts and architecture they are accustomed to so as to meet the needs and aspiration of those productive users and their socio-cultural satisfaction.

• **Zoning of activities**

The primary purpose of zoning is to segregate uses that are thought to be incompatible. The Master Plan and building design has been done to provide a comprehensive, forward looking and integrated planning framework for sustainable development defining different activities and unnecessary movements but also add value to the particular spaces. Meanwhile, considerations are given to achieve an integrated network of various space, while avoiding interference of activities within the spaces.

• **Flexibility and Interchangeability**

As a need for flexibility and interchangeability of architecture has been increasing as recent functional demands, the consultant has adopted the flexible design strategies with proper system for structural grid, enclosure, services, lightening, acoustics, interior finishing, partitions, etc. on modular or flexible principles allowing more future serviceability that is capable of experiencing extensive reconfiguration through its life.

• **Accessibility and Circulation**
The quickest way to spot a good plan is to study its circulation patterns. The planning must be self-explanatory; hence the building has been designed to yield safe, comfortable, clear and unobstructed personal mobility to desire lines, for people of all ages and abilities meanwhile knitting together the different activities for better connectivity. The design is inclusive of consideration given to various types of disabilities including those with mobility, visual, learning, speech and hearing impairments. Lifts as alternatives to stairs has been installed to cater the mass flow within the building.

- **Safety and Security**

All human beings have a very deep and fundamental need for a degree of stability, which can be linked with the safety and security aspect. In professional responsibility basically four fundamental principles of all-hazard are incorporated.

1. Plan for Fire Protection
2. Protect Occupant Safety and Health
3. Natural Hazard Mitigation
4. Provide physical security for building occupants and assets

- **Sustainable and Environmentally friendly design**

The design aims to manage the ecosystems for sustainable development through good structure, layout and design of building system, selection of material that reduces the resource requirements in terms of energy demands, water and land take, and help sustain natural ecosystems as well as helps to mitigate against flooding, pollution and overheating. This also contributes to an environment friendly, easy maintenance and cost effective design solution over long run of building life.

- **Other Technical Considerations**

1. Building services and systems incorporated to meet today's heating, ventilating, and air conditioning systems, power, lighting, electronic and communications systems, fire protection system, energy and other sustainability standards or requirements.
2. Access to windows and view, opportunities for interaction and control of one's immediate environment for improving workplace satisfaction.
3. Emphasis on providing access to natural light and views for psychological well-being of office workers.
4. Acoustical environment designed and integrated with the other architectural systems and furnishings.
5. Technical connectivity to have a distributed, robust, and flexible IT infrastructure identifying all necessary technological systems and provide adequate equipment rooms and conduit runs for them.
6. The library space includes display spaces and reading, meeting and electronic workstations.
Site Accessibility and its surroundings

The proposed site with an area of 4067.85sq.m is prominently located at Jamal, along the Kantipath in the heart of Kathmandu city, with easy access to public transportation, yet at walking distance from neighborhood community. The road leads to Lainchour, Lazimpat towards the north and to Ranipokhari towards the south. The site faces the Rastriya Nachghar ((National Cultural Cooperation) on its west direction opposite to Kantipath and is attached to Vishwojyoti Mall premises on its south side.

The master plan
The master plan of proposed Nepal National Building visibly consists of two major blocks.

Block-A: Main Library building

Block-B: Archive, Administration, Canteen and Conference hall

Block-A and Block-B are interconnected together with a common centrally placed majestic lobby block to result a combined panoramic look. This practice not only sustainably utilizes resources and precious spaces but also allows the users to flexibly adapt the building use in time of need. Other most needed technical services and amenities encompassed within the Master Plan includes outdoor parking area (cars and motorbikes), ATM facilities, U.G water tank of 1,60,000 lit capacity, beautiful landscaped garden, rechargeable pits, STP and Soak Pit, substation and minor maintenance block, boundary wall with entry and exit gates, well-designed landscaped garden, infrastructures as deemed necessary such as surface drainage system, sewerage system, water supply and waste management system, firefighting system, filtration plant, proper security system.

- **Amenities and facilities (major sections) incorporated within the building**

The Nepal National Library possess diverse variety of collections; traditional form of printed books including periodicals, manuscripts, archival material, maps, photographs, audio and video recordings, etc. Nowadays, an ever-increasing number of digital items are also to be incorporated into the collections. Besides, from users’ and visitors’ point of view who appreciate the functionality of the building, it is equipped with modern and intelligently designed facilities spreading over floor area of 14,742sq.m as follows:
Basement
Double basement facilities with separate entry and exit ramp.
- lower basement with 41 cars parking facility and miscellaneous storage space
- Upper basement with 18 cars parking facility, 4 wheel chair space and book storage of about 200,000 book capacity, maintenance section, lifts, MDB room etc.

Ground floor
Common Block:
- Majestically designed entrance Portico/drop off zone and foyer common for both Block having provision of separate ADA access, valet parking and security check service.
- Spacious and welcoming double height common lobby constituting a common lift that overlooks the outer surroundings, the reception and registration counter, service room, infirmary and public rest rooms facilities at convenient yet concealed location.

Block A
- Conveniently placed circulation core with one set of passenger lift and a set of comfortably designed staircase along with emergency exit.
- Atrium and landscaped garden and waiting/reading lounge.
- Reading/waiting lounge overlooking the atrium.
- Visually impaired section with in-built rest room facilities for male and female.
- Children section with play room and storage room that opens up to outdoor landscape play area.

Block B
- Mobile Book Archive

First floors
Common Block:
- Refreshment and recreational facility
- 2 numbers of Group study/ discussion

Block A
- Reading/waiting lounge
- Old friendship study section
- Hearing impaired section

Block B
- Mobile Book Archive

Second floor
Common Block:
- Exhibition gallery with supporting Audio/visual hall
- 2 numbers of Group study/ discussion

Block A
- Reading/waiting lounge
- Young friendship study section
- Research section.

Block B
- Mobile Book Archive

**Third floor**

**Common Block:**
- Physically common block terminates from this floor limiting itself as a covered connecting corridor between Block A and Block B.

**Block A**
- Reading/waiting lounge
- General study section-1
- General study section-2
- Study/meeting room

**Block B**
- NNL Administration section
  (Reception/waiting, Chief Librarian's office, ISBN and ISSN section, Bibliography, Record room, meeting/training room, pantry, Deputy Librarian's office, legal depository, inter library loan section, account, administration, record room, workstation)

**Fourth floor**

**Block A**
- Journal/periodical section-1
- Reading/waiting lounge
- National Language section
- Thesis section

**Block B**
- Indoor Dining hall/restaurant
- kitchen and its facilities
- Semi covered outdoor dining overlooking the street view of Kathmandu

**Fifth floor**

**Block A**
- Manuscript and rare book collection
- Book offered by eminent scholars
- Award winning books
- Reading/waiting lounge
- English language section
- Journal/periodical section-1

**Block B**
- Conference hall lower gallery of 390 people capacity along with separate VIP lounge and support room.
- Pre/post function lobby

**Sixth floor**

**Block A**
- ICT section with computer lab
- 70 person capacity conference hall
- reading/waiting lounge
Block B
- Conference hall upper gallery of 305 people capacity
- Pre/post function lobby

Seventh floor

Block A
- 340 capacity multifunctional hall with room
- Pre/post conference lobby

Aforementioned facilities is distributed among Block-A and Block-B combined by a common lobby in different floors. Detailed design has been developed with respect to the framework hence developed.

![Floor Area Summary of the proposed Nepal National Library](image)

**Figure: Floor Area Summary of the proposed NNL**

### 3.4 Key Technical Issues Taken into Consideration on Making New NNL Building Earthquake Resistant

Earthquake Resistant Building is the structure that is designed in such a way to prevent collapse and to withstand the earthquakes likely to occur at the location of construction. Seismic design provides the building with suitable stiffness, strength, configuration and ductility (Arnold et al., 1982). The basic requirements of seismic design are depending on the structure type, the location of the structure and application of seismic design and criteria (Omori F. 1900). The stability of ground is also needed before starting the construction. Earthquake resistant construction refers to the implementation of the seismic design and building codes for ensuring that the building structures survive through earthquakes.

The chosen structural system for the newly proposed Nepal National library (NNL) is Reinforced cement concrete (R.C.C) structure. RCC is a composite material made of concrete and steel reinforcement. The concrete may be assumed to work purely in compression whereas the reinforcement is predominately subjected to tension. Added reinforcement not only increases the strength but also works fair in preventing the temperature and
shrinkage. Therefore, reinforcing steel is added in the tension zone to carry all the developed tensile stresses. Reinforced concrete structures are considered much safer as concrete resists compression forces, and reinforcing steel resists tensile forces produced by an earthquake. The exceptional ductility of the steel to resist tensile forces, coupled with the rock-like ability of concrete to resist compression make reinforced concrete an ideal material in earthquake prone zones like Nepal. Reinforced concrete structures produce three most important earthquake resistance properties, namely, stiffness, strength, and ductility. It is due to this reason that modern reinforced concrete buildings were found to survive these recent earthquakes with rarely any significant damage.

However, the crucial fact is that, for safety, earthquake-resistant construction techniques are as important as quality control and using correct materials. In order to make new NNL building earthquake resistant following considerations are taken into account. (ERTECH, 2020)

- **Strict Adherence to The Relevant Building Code Standards, Bye-Laws and Other Legislations**

Nepal has designated seismic zones ranging from zone IV to V that is seismically active zones and where priority has to be given to seismic design. It discusses on detailed design guidelines, requirements, specifications and procedures for building construction as well as on choice and selection of materials and its properties. NNL is designed in accordance with Indian standard code for load calculation, structural analysis and design. The applied superimposed and live load is determined in accordance with occupancy using IS 875 (Part 1)-1987, IS 875(Part 2)-1987. For seismic load IS 1983-2016 is used. For design of RC members IS 456 2000 whereas for steel members IS 800 2007 are adopted and for various detailing including ductile detailing for RC structures subjected to seismic forces IS 13920:2015 is used. Considering the requirements of service and seismic loading the structure is prone to, detail structural analysis and design is carried out.

- **Building Site Location And Geometry**

The purpose of this report is to summarize structural analysis and design of proposed Nepal National Library (Educational Building) to be constructed at Jamal, Kathamandu, Nepal. This building project includes three structural blocks (A1, A2 & B). Block A1 has 10 stories (including 2 basements), Block A2 has 6 stories (including 2 basements) and Block B has 9 Stories (including 2 basements) separated by the seismic gap as calculated.

The basic dimensions of Block A1 are Lx=35m, Ly=21m and total height (including basement) =35.6m and that of Block A2 is Lx= 18.5m, Ly= 20.2m and total height (including basement) = 20.3m. Similarly, the basic dimension of block B are Lx=23.05 m, Ly= 41.5m and total height (including basement) = 3265m

- **Basic Structural System**

Special Moment Resisting Reinforced Concrete Frame is used as the basic structural system. The typical floor diaphragms of the building are of reinforced concrete solid slab of 150 mm and 200mm thick. The varying sizes of columns ranging from 500 x 500mm, 500 x 650mm, 650 x 650mm, 1200x500mm, 1250x 500mm, 1400x 500mm, 1500 x 500mm to 1800 x 500mm and the sizes of beams ranging from 400 x 700mm to 230 x 450 mm are used. The thickness of all shear walls are 400mm(unless specified in drawing).The foundation system of the building is raft foundation of 1500mm thickness on top of pile (diameter 800mm and length 18m from the bottom of raft).
• Material Specification
Rebar: Fe500 D
Structural Steel: Fe 250
Grade of Concrete: M25 (Foundation), M30 (Beam & Slab), M35 (Column & Shear Wall)

• Assumption In Loading As Specified Code

Dead Load:
Comprises of all the self-weight of all the components of the building each floor wise
Floor finish: =1.2 KN/m^2 as per IS 875-Part2-1987 k
Unit weight of Brick Masonry wall = 19 KN/m^3 as per IS 875-Part2-1987
Unit weight of Materials: Reinforced Concrete = 24.5 KN/m^3 as per IS 875-Part2-1987

Live Load: As per IS 1893(Part 2)-1987
Live load = 6 KN/m^2 for Book Storage/Stack Room (Book Stack limited to 2.2m)
For staircases, corridors and passages = 4 KN/m^2
Reading Rooms with Book Storage= 4 KN/m^2
Reading Rooms without Book Storage= 3 KN/m^2
Accessible Roof= 1.5 KN/m^2
In-accessible Roof = 0.75KN/m^2

Seismic Parameter: As per the recommendation and guide lines provided in IS 1893 -2016
Analysis Method: Linear Static & Response Spectrum
Site Type: III
Zone factor: Z=0.36 (Zone V)
Importance factor: I=1.5 [Educational building]
Response reduction factor: R=5 [Special Moment Resisting Moment frames]

Analysis Result:

Modal Mass participation: Structure is analyzed for 30 modes. 65% of modal mass is exceeded at mode 3 in both x and y direction for all blocks. At mode 30, more than 90% is
exceeded in both x and y direction. The fundamental lateral natural periods of the building in the two principal plan directions are away from each other by more than 10% of larger value.

**Base Reaction:** Analysis was done by linear static and response spectrum method. Scale factor for the analysis of response spectrum method for x and y direction are respectively 1.776 and 1.48 for Block A1, 1.222 and 1.63 for Block A2 and 1.338 and 1.32 for Block B.

**Storey Stiffness:** Analysis was checked for storey stiffness at all floor levels. Analysis was maintained for stiffness to be less than that at lower storey as per IS 1893:2016.

**Torsion:** The ratio of maximum and minimum joint displacement at two ends along x and y direction was checked and maintained to be less than 1.5 as per IS 1893:2016. RC structural walls were added to maintain these criteria as per requirement in analysis.

**Storey Drift:** Storey drift for earthquake loading is auto generated from program. The max storey drift ratio for block A1 is 0.0022(X) and 0.0024(Y), for block A2 is 0.0029(X) and 0.0017(Y), similarly for block B is 0.00199(X) and 0.0025(Y). Hence, it is maintained to be less than 0.004% of storey-height.

**Centre of Mass and Rigidity:** Centers of mass and rigidity is calculated to determine the eccentricity ratio. 5% of eccentricity ratio is checked. The structure is again analyzed for the exceeded value for eccentricity.

**Mass Irregularity:** For all blocks, ratio of storey mass of above and lower floor is maintained to be less than 1.5 as per IS 1893:2016.

- **Foundation Analysis And Design**

The foundation system has been designed as Raft pile foundation based on the load of super structure and type of soil underneath received from the geotechnical investigation. Bearing capacity of soil for Block A1 & A2 is 70 KN/m$^2$ and that for Block B is 75 KN/m$^2$.

The thickness of raft is 1500mm and 1800mm. The raft foundation rests on top of piles of diameter 800mm and 18m length (from base of raft foundation). Concrete grade used in for raft and pile is M25.
Figure: Pressure on Soil Exerted by Raft Foundation with Pile of Block A1

Figure: Pressure on Soil Exerted by Raft Foundation with Pile of Block B

- Design Of Beams And Columns

Figure: ETABS model of Block A1 & A2
The structural modeling, analysis and design is done using ETABS 2017.0.1. The seismic analysis of the structure is done as per IS1893-2016 and RC design is done as per IS 456-2000. The ductile detailing rules for column, beam, foundation and the beam column junction, etc. concerning the stirrups size, spacing, lap length, confining of joints are done as per the IS 13920-2015. The foundation system has been designed as Raft pile foundation based on the load of super structure and type of soil underneath received from the geotechnical investigation. Hence, the proposed design satisfies the key requirement of the building codes.

- **Foundation**
  1. Geo technical investigation has been carried out to find out the Bearing capacity of soil. The building is allowed to rest on a rigid raft foundation on piles taken to a firm stratum. Bearing capacity of soil for Block A1 & A2 is 70 KN/m² and that for Block B is 75 KN/m². The data obtained has been used for foundation design of the structure.
  2. Protection pile of 600mm diameter and 14 m length paced at 600mm center to center spacing is to be done.
  3. The thickness of raft is 1500mm and 1800mm.
  4. The raft foundation rests on top of piles of diameter 800mm and 18m length (from base of raft foundation). Concrete grade used in for raft and pile is M25.

- **Superstructure**
  1. Concrete grade used in columns and shear walls is M35, for beam and slab is M30. Grade of steel used for rebar is FE500D and for structural members is FE250.
  2. Cover to main reinforcing steel shall be in accordance with IS456 & as specified: Slab & staircase: 20 mm, Beam: 35 mm, column: 40 mm and footing: 50 mm. Minimum reinforcing laps shall be in accordance with IS13920.

- **Other considerations**
1. Seismic Expansion joint: Seismic expansion joints are frequently introduced to separate wings, or other parts of a single building. A seismic joint typically creates a separation between the adjacent buildings or parts of buildings and is designed to safely absorb the heat-induced due to expansion and contraction of construction materials, to absorb vibration, to hold parts together, or to allow movement due to ground settlement or earthquakes, static load deflection, live load deflection etc. The joint allows separation of building that will allow the building to expand and release stresses thereby preventing release of stresses by cracking. Because the joint bisects the entire structure, it marks a gap through all building assemblies—walls; decks; foundation floors and walls; roofs, floors; interior floors; etc. This gap is filled with a kind of elastic element to restore the waterproofing, fireproofing, soundproofing, air barrier, roof membrane, trafficable surface and other functions of the building elements it bisects. The entire building complex is simplified into simple geometric plan with insertion of 2 seismic joints at the place where building shape tends to change its direction.

2. Shear wall: Shear walls are a type of structural system that provides lateral resistance, Horizontal, and Shear Force to a building or structure. They resist in-plane loads that are applied along its height. The applied load is generally transferred to the wall by a diaphragm or collector or drag member. Shear walls are a useful building technology that helps to transfer earthquake forces and helps a building keep its shape during movement. Thus, the building is able to resist the larger forces of an earthquake while allowing designers more freedom to arrange building elements. Shear walls are provided at places as deemed necessary in analysis and design carried out as per the Building Code.

3. Strong column weak beam: In case of failure of structure, beam fails before the column giving a warning sign which proves vital during an earthquake. The design is based on strong column weak beam principle.

4. Sill, lintel band: R.C.C band is provided throughout the run along wall at lintel and sill levels, passing over doors and windows.

5. Horizontal and vertical bands: It makes walls behave well during earthquake shaking by making them act together as a box along with the roof at the top and with the foundation at the bottom

6. Consideration of vertical irregularities like soft storey construction: Soft stories have been the reason for the damage of many structures in the past earthquake. Consideration has been given to it.

7. Consideration of vertical irregularities like soft story construction: Soft stories have been the reason for damage of many structures in the past earthquake in Kathmandu. Consideration is given to it.

8. Ductile detailing: Detailing for Column and beam joint, Lap splice in column and beams, sufficient development length Transverse reinforcement hooks angle in column, is done which is strong and ductile enough to survive the shaking with an acceptable damage.

4. Discussion

Gorkha earthquake 2015, has been a lesson learnt experience to engineers, architects, builders and administrators for improving planning, design analysis, and construction practice and for enforcement and monitoring of design codes. It was found that most of building suffered severe damage or collapsed due to non-seismic design, low quality construction, improper design etc. They were mostly, old, non-engineered, adobe and unreinforced masonry buildings which are
not good at resisting to earthquakes. In addition, some engineered buildings are also damaged or collapsed due to poor workmanship and quality of construction materials.

According to current estimates (Matthys, 1989), more than 70% of the existing inventory of structures worldwide are masonry. Most were designed and built prior to the development of “engineered masonry structures” and may not be able to satisfy the requirements for horizontal forces. Even most of them were designed to earlier building codes, which have been proven to be incomplete or even insufficient. These buildings include many of those with historical interest and are often protected by cultural conservation laws. Hence, measure such as retrofitting can be taken to increase the structural system to improve resistance by increasing strength and ductility in order to protect traditional classical building, Harihar Bhawan, instead of completely demolishing them.

All the major earthquakes proved the fact that the casualties were mainly due to the failure of infrastructures. Earthquake strikes suddenly, violently and without warning at any time. Although there are no guarantees of safety during an earthquake, identifying potential hazards a head of time and advance planning to save lives and property damage is crucial. Hence it is mandatory to do the proper seismic analysis and design to structural against collapse and make the infrastructures we construct today an earthquake resistant in order to mitigate the potential devastation caused by future earthquakes in a most effective way, yet there should be no compromise in building compliance.

A contemporary earthquake resistant solution has been presented to the Nepal National Library which has been struggling to re-settle after partially collapse of the Harihar Bhawan. Attempt has been made to make the building not only aesthetically appeasing to the eye revealing rich culture, tradition and architecture of our country but also functionally and structurally faultless.

5. Conclusion and Recommendation

The present paper reveals several reasons that made neoclassical architecture like Harihar Bhawan partially collapse. Such buildings carry huge importance from traditional as well as architectural point of view. Proper analysis of the structure is important so that retrofitting measures can be carried out to preserve these structures and make them structurally sound.

Also, R.C.C structures have become a trend in Nepal. Their ductile property has proven to be good resistant to earthquake forces considering that they are designed correctly and constructed well. This paper highlights the design consideration for architecture of the prestigious National Library of Nepal. It also presents the earthquake resistant design and details of the proposed library building. With its traditional look, carefully tailored environment and uncompromised facilities it incorporates, the proposed NNL building is sure to achieve its mission and roles in the 21st century and to make its assets accessible to researchers and to the people of all nationalities.

Recommendations

1. Policy for effective implementation of Building Codes : Considering the earthquake vulnerability of the country and the destruction it caused in terms of human loss and damage of buildings and infrastructure and its post disasters effect a nation has to go through socially and economically, Nepal government is strongly recommended to impose effective implementation of Building Codes to make the buildings and other infrastructures earthquake resistant and more strictly on public building alike NNL.

2. Develop guidelines for dynamic seismic analysis and design: It is recommended that extensive studies should be carried out in seismology and earthquake resistant construction for developing and updating specifications codes and engineering
parameters for dynamic seismic analysis and design and construction of several types of structures.

3. Inclusion of seismic provisions for those newly developed building materials: Recent advances in materials science have suggested new materials with improved seismic performance of concrete structure like: fiber reinforced concrete, high-strength concrete, high-strength lightweight concrete, polymer concrete, expansive and self-stressing concrete etc. Building code also needs an upgrade regarding update of seismic provisions for those newly developed building materials, structural elements and systems in construction for the better structural performance of buildings against earthquakes.

4. Inclusion of smart technologies for seismic design: It is also recommended to introduce new technologies including base isolation, Energy dissipation device, and Spring Base Isolator structure in the building code regarding seismic design.

5. Sustainable and Environmental friendly design: Buildings should not be built haphazardly. Especially in the Kathmandu Metropolitan, environmental considerations should be taken into account. Sustainable construction practices are encouraged.

6. Proposed NNL building is recommended to be built in Daachi Appa as it is designed considering it and since those bricks are traditionally made.

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References


