PROBABILISTIC SEISMIC HAZARD AND RISK ANALYSIS

(KATHMANDU VALLEY –BUDHANILKANTHA)

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***Abstract*: Devastating Gorkha Earthquake of 25 April and 12 May 2015, has displaced around 8 million people in Nepal, where 498,852 private houses and 2,656 government buildings were completely destroyed. Hundreds of settlements were shattered leaving homeless across 31 districts with 14 districts suffering the highest impact. Around 250 thousand private houses and 3600 government buildings were partially damaged, which needs to be restored back. Initial reports from Post-Disaster Needs Assessment (PDNA) states requirement of NPR 669 billion for reconstructing damaged properties and infrastructure. In this Scenario, for a country like Nepal having Kathmandu as its capital city, the seismic hazard analysis is a most to mitigate the future risk and preparedness. This helps to aware the residing people and government as well as non-governmental organizations to take needed precautions for minimizing the Risk of Pre and Post-disaster. During this analysis, number of typical residential buildings will be taken and analysed for seismic hazard. The conclusion will be drawn for number of typical buildings and its future risk based on property and life casualty.**

***Index Terms - Se*ismic hazard, Risk Analysis, Post disaster assessment, Evaluation phase**

1. INTRODUCTION

Devastating Gorkha Earthquake of 25 April and 12 May 2015, has displaced around 8 million people in Nepal, where 498,852 private houses and 2,656 government buildings were completely destroyed. Hundreds of settlements were shattered leaving homeless across 31 districts with 14 districts suffering the highest impact. Around 250 thousand private houses and 3600 government buildings were partially damaged, which needs to be restored back. Initial reports from Post-Disaster Needs Assessment (PDNA) states requirement of NPR 669 billion for reconstructing damaged properties and infrastructure.

Nepal lies in the central part of the Himalayan chain and seismically active zone. The Himalaya is the result of collision between Indian continent and Eurasia/ Tibetan plate about 55 Ma. The subduction of the Indian continent beneath Tibetan Plate is 20mm per year according to GPS measurement (Avouac, 2003). This subduction creates convergence which is absorbed by convergence across the plate boundary resulting different magnitude earthquake. Nepal has a long history of destructive earthquakes.

This intensity of Earthquake has severe effect on central development region including the capital Kathmandu itself. Kathmandu itself being a severe earthquake prone zone have a history of Massive earthquakes.

This paper is hence a effort to find out the vulnerability assessment of different structures present in Kathmandu Valley especially ay Budhanilkantha area. This is carried out by following certain guidelines of ***FEMA*** (Federal Emergency management System).

The FEMA guidelines is a universal accepted procedure for Rapid Visual careening of Buildings for potential seismic Hazard.

The objective of paper involves finding out potential risk on structures at respective seismic zone which has threat on life and property with various casualty involved.

The various types of structures may be categorized into following types:

A. Commercial Structures

B. Residential Structures

  I. RCC frame Structure (Concrete)

  II. Masonry Structures

    - Brick Masonry on Cement Mortar
    - Stone Masonry on Cement Mortar
    - Stone Masonry on Mud Mortar
    - Brick Masonry on Mud Mortar

C. Historic Monuments

This method of Rapid Visual Screening(RVS) is recent adopted procedure by Nepal Government(NG) on different 31 districts to find different grades of seismic Hazard and its impact on residential buildings.
Such screened structures are then either:

I. Retrofitted,

II. Restored,

III. Demolished based on score of structure during rapid visual screening.

2. TERMINOLOGY

2.1. Definitions

Probabilistic

It refers to based on or adapted to a theory of probability, subjected to or involving chance of variation. It is also the measure of the likelihood that an event will occur.

Seismic Hazard

It is the probability that an earthquake will occur in a given geographic area, within a given window of time, and with ground motion intensity exceeding a given threshold. With a hazard thus estimated, risk can be assessed.

Risk Analysis

Risk analysis is the process of defining and analyzing the dangers to individuals, businesses and government agencies posed by potential natural and human-caused adverse events. A risk analysis report can be either quantitative or qualitative.

In quantitative risk analysis, an attempt is made to numerically determine the probabilities of various adverse events and the likely extent of the losses if a particular event takes place.

Qualitative risk analysis, which is used more often, does not involve numerical probabilities or predictions of loss. Instead, the qualitative method involves defining the various threats, determining the extent of vulnerabilities and devising countermeasures should an attack occur.

Probabilistic Seismic Hazard And Risk Analysis (PSHRA)

Hence from the definitions above PROBABILISTIC SEISMIC HAZARD AND RISK ANALYSIS can be extracted as the risk which is probable to occur and its consequences to occur due to any extent of seismic activity at any particular region. It is a methodology that estimates the likelihood that various levels of earthquake-caused ground motion will be exceeded at a given location in a given future time period. Due to large uncertainties in all the geosciences data and in their modeling, multiple model interpretations are often possible.

2.2. SCOPE OF PSHRA

Even though it has never been validated by objective testing, Probabilistic Seismic Hazard Analysis (PSHA) has been widely used for almost 50 years by governments and industry in applications with lives and property hanging in the balance, such as deciding safety criteria for nuclear power plants, making official national hazard maps, developing building code requirements, and determining earthquake insurance rates. PSHRA rests on assumptions now known to conflict with earthquake physics. Many damaging earthquakes, including the 1988 Spitak, Armenia, event and the 2011 Tohoku, Japan, event, have occurred in regions relatively rated low-risk by PSHRA hazard maps. No extant method, including PSHRA, produces reliable estimates of seismic hazard. Earthquake hazard mitigation should be recognized to be inherently political, involving a trade-off between uncertain costs and uncertain risks. Earthquake scientists, engineers, and risk managers can make important contributions to the hard problem of allocating limited resources wisely, but government officials and stakeholders must take responsibility for the risks of accidents due to natural events that exceed the adopted safety criteria.

3. BACKGROUND

Kathmandu Valley

The Kathmandu Valley (Nepali: काठमाडौं उपत्यका), historically known as Nepal Valley or Nepa Valley, lies at the crossroads of ancient civilizations of Asia, and has at least 130 important monuments, including several pilgrimage sites for Hindus and Buddhists. There are seven World Heritage Sites within the valley.

The Kathmandu Valley is the most developed and populated place in Nepal. The majority of offices and headquarters are located in the valley, making it the economic hub of Nepal. It is popular with tourists for its unique architecture, and rich culture that includes the highest number of jatras (street festivals) in Nepal. The valley itself was referred to as "Nepal Proper" by British historians.In 2015, Kathmandu Valley was hit by the April 2015 Nepal earthquake. The earthquake caused thousands of deaths and destruction of many infrastructures.

Kathmandu valley is bowl-shaped. Its central lower part stands at 1,425 metres (4,675 ft) above sea level. Kathmandu valley is surrounded by four mountain ranges: Shivapuri (at an elevation of 2,800 metres or 9,200 feet), Phulchowki (2,795 metres or 9,170 feet), Nagarjun (2,825 metres or 9,268 feet) and Chandragiri (2,551 metres or 8,369 feet). The major river flowing through the Kathmandu Valley is the Bagmati.

Its geographic co-ordinate is: 27□42’14” N 85□18’32” E

Fig 1. Kathmandu Valley

Seismic History Of Kathmandu Valley

Kathmandu has a very massive history of Earthquake from Decades. The History of Them are summarized as below with its intensities:

I. 1255 AD: Severely Damaged Kathmandu
II. 1260 AD: Moderately Affected
III. 1408 AD: Collapse of Several Monuments
IV. 1681 AD: Destructed many Houses and loss of Temples
V. 1767 AD: Moderately Affected
VI. 1810 AD: Building temples were Damaged, Numbers of casualties were less
VII. 1823 AD: Moderately Affected
VIII. 1833 AD: Completely destroyed Kathmandu Valley, 4214 numbers of houses were collapsed
IX. 1834 AD: Moderate with few shocks
X. 1934 AD: Nepal Bihar earthquake, Highest number of casualties
XI. 1980 AD: Buildings were damaged, Loss of life and property
XII. 1988 AD: Completely destroyed many Life's and Loss of Property
XIII. 1993 AD: Moderately Affected
XIV. 1994 AD: Buildings and houses were damages with Several injuries
XV. 1997 AD: Moderately Affected
XVI. 2011 AD: Several Injuries and Buildings were collapsed

Fig 2: Destruction on Property due to Earthquake at Kathmandu Region

Fig 3: Destruction on Monuments due to Earthquake at Kathmandu Region

Fig 4: Destruction on Residential Buildings due to Earthquake at Kathmandu Region

Fig 4: Casualty on Human Life due to Earthquake at Kathmandu Region

Budhanilkantha

Budhanilkantha is situated at the foot of Shivapuri hills with plane fertile land and sloppy geographical structure. The structures here are of different types since it is a village area at past and have some diversity on old and new types of residential structures. It is rich at natural resources and monuments which has their own significances and are source of many people's faith. The main Iconic statue of God Budhanilkantha is on the vicinity of the locality and is severely destroyed by the recent 2015 earthquake.

The geographical coordinate of this area is: 27□46′41″ N 85□25′44″ E

Fig 5: Budhanilkantha Locality resting on Shivapuri Hill

Why Pshra On Budhanilkantha Locality:

Budhanilkantha is a municipality located at Kathmandu valley with variation on its geographical diversity. It is diverse on its land distribution which has resulted on different types of substructures built here in it.

Recent earthquake has some severe effect on life and property on this region. Being very old residential area, the types of structures found here are also of various kinds:

- Commercial Buildings
- Residential buildings
  - RCC
  - BMC
  - SMC
  - BMM
  - SMM
- Historic Temples and Monuments

The land structure here varies from sloppy hill to plain land. Hence giving a diversified structural assembly on structures.

Budhanilkantha being old habitat place, and a rapid decentralizing hub at Kathmandu lot of old and typical structures as well as modern structures are present. So, the seismic vulnerability is also a major concern in this region for all old and new structures which has a threat on life and property.

Probabilistic seismic hazard and risk analysis in this region gives further idea about the vulnerability and risk allocated along with it. After PSHRA the identification of vulnerable structures are done and risk can be therefore figure out. For those structures having vulnerability assessment their further restoration can be done by retrofitting technique or restoration of entire building.

Hence Probabilistic Seismic Hazard and risk Analysis play a vital role on risk minimization and saving of life and property of people of this region.

4. METHODOLOGIES OF RISK ANALYSIS

The methods adopted on the Risk analysis on Seismic hazard at Budhanilkantha, KTM involves:

I. Finding out history of seismic activity on Kathmandu valley

Seismic history of Kathmandu has as already been discussed it can be concluded that Kathmandu is very prone to seismic activity and have anytime chance of bigger to smaller earthquakes.

i) Various Governmental Statistics

Lots of human lives as well as property have been lost on different earthquakes at different histories. Recent earthquake has made nearly 10,000 human life loss which had major on Kathmandu Valley. The structural damage as well as collapse of many Residential as well as commercial buildings were observed.

ii) Its various effect on different structural components including loss of life and property

The seismic effect on structures were very closely seen. Various types and modes of collapse and various faulty construction practise results have made realised a lot on past earthquake experiences.

II. Locating different types of structures present on Budhanilkantha area

i. Residential Building Types

ii. Monuments and Historical assets

III. Progress on recent construction methodology

Budhanilkantha is the present hub of centralization at Kathmandu Valley. Many numbers of Residential buildings are under constriction each year and free space is getting rare. The construction practise has been slightly changed after Gorkha Earthquake leading to safer construction.

IV. Sampling different structures which are inbuilt

For PSHRA different structures were sampled using FEMA model using its own guidelines and Techniques.
The Sampled structured were then observed at different Tiers of observation and suitable conclusion have been drawn.

5. RAPID VISUAL SREENING OF BUILDINGS AND ITS SEISMIC EVALUATION USING FEMA MODEL

FEMA (Federal Emergency Management Agency) is the agency of United States Department of Homeland security. The Primary Purpose of this Agency is to coordinate the response to a disaster that has occurred. The major part of FEMA's charter is to provide on the ground support of disaster recovery. The agency provides state and local governments with experts in specialized fields and also provides funds. It has existed on one form or another for over 200 years.

FEMA's Mitigation Directorate is responsible for programs that take action before a disaster, in order to identify risks and reduce injuries, loss of property, and recovery time. The agency has major analysis programs for floods, hurricanes and tropical storms, dams, and earthquakes.

FEMA works to ensure affordable flood insurance is available to homeowners in flood plains, through the National Flood Insurance Program, and also works to enforce no-build zones in known flood plains and relocate or elevate some at-risk structures.

FEMA offers a large number of training classes, either at its own centres, through programs at the state level, in cooperation with colleges and universities, or online. The latter are free classes available to anyone, although only those with U.S. residency or work eligibility can take the final examinations. More information is available on the FEMA website under the "Emergency Personnel" and "Training" subheadings. Other emergency response information for citizens is also available at its website.

FEMA runs the Incident Workforce Academy, a two-week emergency preparedness training program for FEMA employees. The first class of the academy graduated in early 2014.

FEMA has led a Public-Private Partnership in creating a National Donations Management Program making it easier for corporations or individuals not previously engaged to make offers of free assistance to States and the Federal Government in times of disaster. The program is a partnership among FEMA, relief agencies, corporations/corporate associations and participating state governments. The technical backbone of the program is an online technology solution called The Aid matrix Network which is managed by the independent non-profit organization.

5.1. Articles of Fema

The FEMA has extracted numbers of articles which gives guidelines for preparedness of different disaster relief techniques. The major articles of FEMA for Rapid visual screening and Risk Analysis are:

I. FEMA 154

II. FEMA 255

III. FEMA 310

5.1.1. Fema 154

FEMA 154 article is related to Rapid Visual screening (RVS) of buildings for potential seismic hazards .The technical basis for the methodology , including the scoring system and its development are contained in the companion FEMA 154 report.

The Rapid Visual Screening (RVS) procedure has been developed for a broad audience, including building officials and inspectors and government agencies and private sector building owners, to Reidentify, inventory and rank buildings that are potentially seismically hazardous. The ***RVS*** uses a methodology based on a "sidewalk survey" of a building and a data collection form. Once the decision to conduct ***RVS*** for community or group of buildings has been made by the ***RVS*** authority.

Completion of data collection form in the field begins with identifying the primary structural, lateral-load-resistant system and structural materials of the buildings. The use of ***RVS*** on a community-wide basis enables the ***RVS*** authority to divide screened buildings into two categories. Those data are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further.

Buildings identified bt these procedures must be analysed in more detail by an experienced seismic design professional because rapid visual screening is designed to be performed from the street with interior inspection not always possible.
Conversely, Buildings initially identified as potentially hazardous by RVS may provide to be adequate.

5.1.2. Fema 255

FEMA's programme for reducing seismic hazards in existing buildings includes development of body of consensus engineering criteria on how to evaluate and reduce the seismic vulnerability of existing buildings comprehensive programme is also concerned with the societal and economic aspects of the seismic rehabilitation of existing buildings.

This article is accompanied by software which presents benefit cost model for seismic rehabilitation of federal buildings.

Benefit cost analysis is a powerful tool which can help determine weather the future benefits of respective seismic rehabilitation are sufficient to justify the present cost of the project. This methodology in this article provides estimates of the benefits of the seismic rehabilitation of federal government buildings. This model is also applicable to state and local government building.

There are two primary intended application for this methodology. First two roughly screen or prioritized a large list of buildings and second, to evaluate in detail one or more specific alternatives on a single building for which detail engineering analysis exists. To evaluate one or more specific rehabilitation options for a single building detail engineering analysis of the alternatives are essential.

The benefit cost model performs the necessary calculations to determine how the expected future benefits of a specific seismic rehabilitation project compare to the cost. This model also generates detailed scenario damage estimates of expected damages other economic losses and casualties for any earthquake. This scenario damage, loss, and casualty estimates may prove useful to decision, makers.

This model is generally used by professionals, Engineers, Architect, design professional and manager. However, a practical knowledge of seismic activity and its relevant information is necessary to fill the data's and on formulated software's.

5.1.3. Fema 310

This article provides a process for seismic evaluation of existing buildings. It deals with instructing the evaluating design professional on how to determine if a building is adequately designed and constructed to resist seismic forces. All aspect of building performance disconsidered and defined in terms of structural, non-structural and foundation/geological hazard issues.

Prior to using this article ***RVS*** of the building may be performed to determine if an evaluation is needed using the article

5.1.4. FEMA 154 And 155.

This article provides a three tired process for seismic evaluation of existing buildings in any region of seismicity. Buildings are evaluated to either the life safety or immediate occupancy performance level.

The use of this article and mitigation of deficiencies identified using this handbook are voluntary or as required by the authority having juridistiction. The design of mitigation measures is not addressed in this article.

This article does not preclude a building from being evaluated by other well-established procedures based on rational methods of analysis in accordance with principles of mechanics and approved by the authority having jurisdictions.

5.2. Application of Fema 310 on PSHRA:

The evaluation process consists of the following three tiers, which are shown in Figure below:

Screening Phase (Tier 1), Evaluation Phase (Tier 2), and Detailed Evaluation Phase (Tier 3). As indicated in Figure, the design professional may choose to (i) report deficiencies and screening recommend mitigation or (ii) conduct further evaluation, after any tier of the evaluation process. The screening phase, Tier 1, consists of 3 sets of checklists that allow a rapid evaluation of the structural, non-structural and foundation/geologic hazard elements of the building and site conditions. It shall be completed for all building evaluations conducted in accordance. The purpose of a Tier 1 evaluation is to screen out buildings that comply with the provisions of this Handbook or quickly identify potential deficiencies.

In some cases, "Quick Checks" may be required during a Tier 1 evaluation, however, the level of analysis necessary is minimal. If deficiencies are identified for a building using the checklists, the design professional may proceed to Tier 2 and conduct a more detailed evaluation of the building or conclude the evaluation and state that potential deficiencies were identified. In some cases, a Tier 2 or Tier 3 evaluation may be required. Based on the ABK research (ABK, 1984), unreinforced masonry buildings with flexible diaphragms were shown to behave in a unique manner. Special analysis procedures provided in were developed to predict the behaviour. Since this special procedure does not lend itself to the checklist format of Tier 1, no Structural Checklists are provided. The design professional must perform the Tier 2 Special Procedure as the first step of the evaluation. The Special Procedure only applies to the structural aspects of the building; Tier 1 Checklists provided for the non-structural elements and for the foundation and geologic hazards issues still apply.

For Tier 2, a complete analysis of the building that addresses all of the deficiencies identified in Tier 1shall be performed. Analysis in Tier 2 is limited to simplified linear analysis methods. As in Tier 1, evaluation in Tier 2 is intended to identify buildings not requiring rehabilitation. If deficiencies are identified during a Tier 2 evaluation, the design professional may choose to either conclude the evaluation and report the deficiencies or proceed to Tier 3 and conduct a detailed seismic evaluation.

Recent research has shown that certain types of complex structures can be shown to be adequate using nonlinear analysis procedures even though other common procedures do not. While these procedures are complex and expensive to carry out, they often result in construction savings equal to many times their cost. The use of Tier 3 procedures must be limited to appropriate cases. The final report serves to communicate the results to the owner and record the process and assumptions used to complete

the evaluation. Each section should be carefully written in a manner that is understandable to its intended audience. The extent of the final report may range from a letter to a detailed document. The final report should include at least the following items:
1) Scope and Intent: a list of the tier(s)followed and level of investigation conducted;
2) Site and Building Data: General building description (number of stories and dimensions),
Structural system description (framing, Lateral load resisting system, floor and roof diaphragm construction, basement, and foundation system),
Non-structural element description (non-structural elements that could interact with the structure and affect seismic performance)
Building type, Performance Level, Region of Seismicity, Soil Type, Building Occupancy, and Historic Significance;
3) List of Assumptions: material properties, site soil conditions;
4) Findings: list of deficiencies;
5) Recommendations: mitigation schemes or further evaluation;
6) Appendix: references, preliminary calculations.

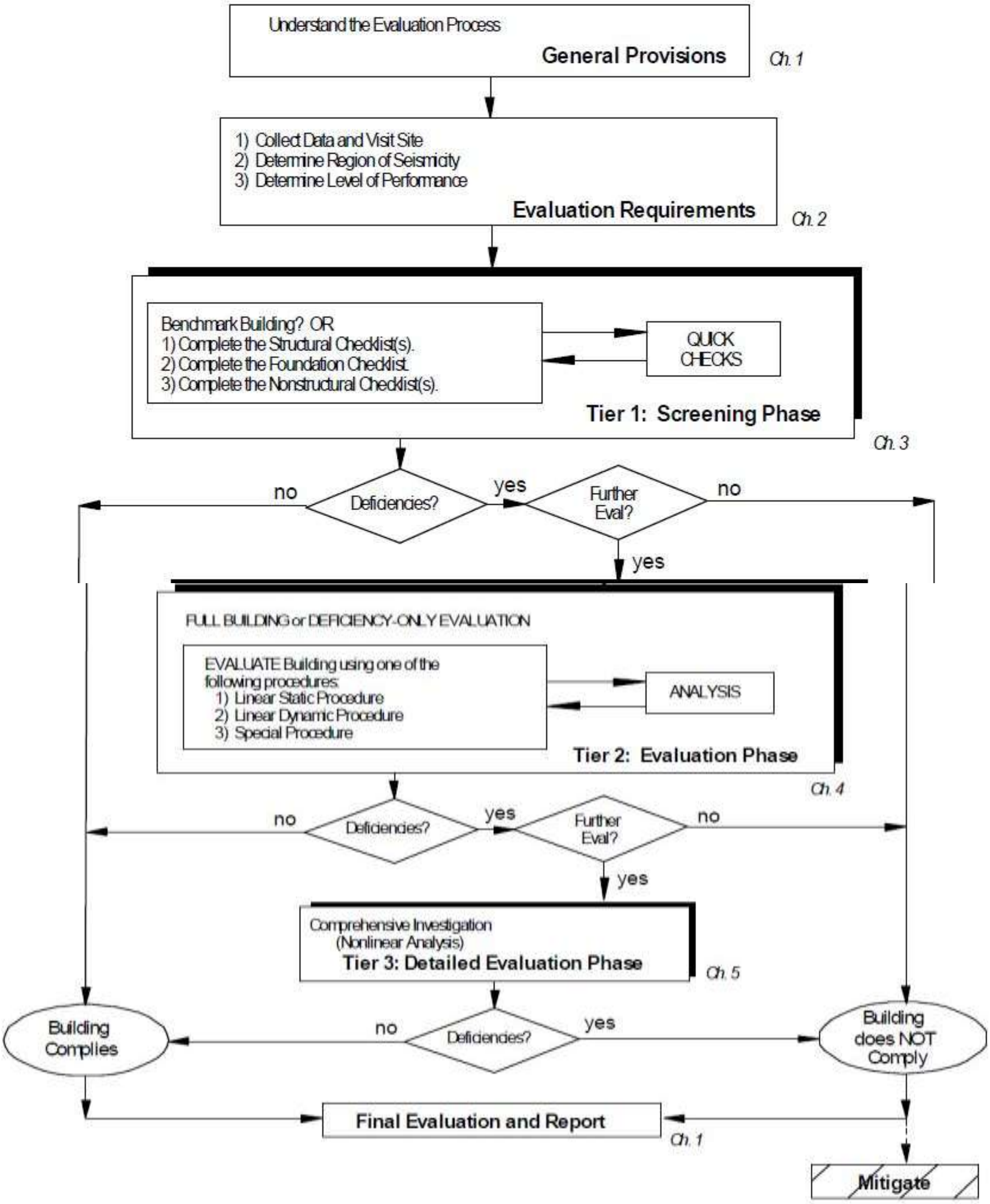

Figure 6: Evaluation Process

5.3. Terminologies

Basic Nonstructural Checklist:
Set of evaluation statements that shall be completed as part of the Tier 1 Evaluation. Each statement represents a potential non-structural deficiency based on performance in past earthquakes.

Basic Structural Checklist:
Sets of evaluation statements that shall be completed as part of the Tier 1 Evaluation. Each statement represents a potential structural deficiency based on performance in past earthquakes.

Diaphragm:
A horizontal structural system that serves to interconnect the building and acts to transmit lateral forces to the vertical resisting elements.

Linear Dynamic Procedure (Ldp):
A tier 2 response spectrum based modal analysis procedure shall be used for buildings taller than 100feet, buildings with vertical or geometric irregularities, and buildings where the distribution of the lateral forces departs from that assumed for the Linear Static Procedure.

Linear Static Procedure (Lsp):
A Tier 2 lateral force analysis procedure where the pseudo lateral force is equal to the force required to impose the expected actual deformation of the structure in its yielded state when subjected to the design earthquake motions. It shall be used for buildings for which the Linear Dynamic or the Special Procedure is not required.

Region of Seismicity:
An area with similar expected earthquake hazard. For simplicity, all regions are categorized as low, moderate, or high, based on mapped acceleration values and site amplification factors as defined.

Rigid Diaphragm:
A diaphragm where the maximum lateral deformation is less than half the average inter-story drift associated with the story.

Tier 1 Evaluation:
Completion of checklists of evaluation statements that identifies potential deficiencies in a building based on performance in past earthquakes.

Tier 2 Evaluation:
The specific evaluation of potential deficiencies to determine if they represent actual deficiencies that may require mitigation. Depending on the building type, this evaluation may be Full-Building Tier 2 Evaluation, Deficiency-Only Tier2 Evaluation, or a Special Procedure Tier 2 Evaluation.

Tier 3 Evaluation:
A comprehensive building evaluation implicitly or explicitly recognizing nonlinear response.

6. EVALUATION PROCESS

Site Visit:
A site visit shall be conducted by the evaluating design professional to verify existing data or collect additional data, determine the general condition of the building, and verify or assess the site conditions.

Level of Performance:
A desired level of performance shall be defined prior to conducting a seismic evaluation. The level of performance shall be determined by the design professional and by the authority having jurisdiction. The following two performance levels for both structural and non-structural components are defined as Life Safety (LS) and Immediate Occupancy (IO).

Region Of Seismicity:
The region of seismicity of the building shall be defined as low, moderate, or high in accordance with Table:

Region of Seismicity[1]	S_{DS}	S_{D1}
Low	$< 0.167g$	$< 0.067g$
Moderate	$< 0.500g$ $> 0.167g$	$< 0.200g$ $> 0.067g$

Figure 7: Region of Seismicity Table

7. SCREENING PHASE

A Tier 1 Evaluation shall be conducted for all buildings after the evaluation requirements of buildings have been completed. Initially, the design professional shall determine whether the building meets the benchmark building criteria.
If the building is not a benchmark building, the design professional shall select and complete the appropriate checklists using another method.

7.1. Tier 1 Evaluation

7.1.1. Structural Checklist

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or no applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this checklist, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Building System

1. LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation.
2. VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.
3. DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose.
4. OVERDRIVEN FASTENERS: There shall be no evidence of overdriven fasteners in the shear walls.

Lateral Force Resisting System

1. REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy.
2. SHEAR STRESS CHECK: The shear stress in the shear walls, calculated using the Quick Check procedure, shall be less than the following values for Life Safety and Immediate Occupancy.
3. STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multi-storey buildings shall not rely on exterior stucco walls as the primary lateral-force-resisting system.
4. GYPSUM WALLBOARD OR PLASTER SHEAR WALLS: Interior plaster or gypsum wallboard shall not be used as shear walls on buildings over one story in height.
5. NARROW WOOD SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to1 for Life Safety and 1.5 to 1 for Immediate Occupancy shall not be used to resist lateral forces developed in the building.
6. WALLS CONNECTED THROUGH FLOORS: Shear walls shall have interconnection between stories to transfer overturning and shear forces through the floor.
7. HILLSIDE SITE: For a sloping site greater than one-half story, all shear walls on the downhill slope shall have an aspect ratio less than 1 to 1 for Life-Safety and 1 to 2 for Immediate Occupancy.
8. CRIPPLE WALLS: All cripple walls below first floor level shear walls shall be braced to the foundation with shear elements.
9. CONNECTIONS

1. WOOD POSTS: There shall be a positive connection of wood posts to the foundation.
2. WOOD SILLS: All wood sill s shall be bolted to the foundation.
3. GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support.

Geology And Foundation Checklist

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Geology Site Hazards

The following statements shall be completed for buildings in regions of high or moderate seismicity.

1. LIQUEFACTION: Liquefaction susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building for Life Safety and Immediate Occupancy.
2. SLOPE FAILURE: The building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure.
3. SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated.

Condition of Foundation

The following statement shall be completed for all Tier 1 building evaluations.

1. FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure. The following statement shall be completed for buildings in regions of high or moderate seismicity being evaluated to the Immediate Occupancy Performance Level.
2. DETERIORATION: There shall not be evidence that foundation elements have deteriorated due to corrosion, sulphate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure.

Capacity of Foundation

The following statement shall be completed for all Tier 1 building evaluations.

1. POLE FOUNDATIONS: Pole foundations shall have a minimum embedment depth of 4 ft. for Life Safety and Immediate Occupancy.
2. OVERTURNING: The ratio of the effective horizontal dimension, at the foundation level of the lateral-force-resisting system, to the building height (base/height) shall be greater than 0.6Sa.
3. TIES BETWEEN FOUNDATION ELEMENTS: The foundation shall have ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Class A, B, or C.
4. DEEP FOUNDATIONS: Piles and piers shall be capable of transferring the lateral forces between the structure and the soil. This statement shall apply to the Immediate Occupancy Performance Level only.
5. SLOPING SITES: The grade difference from one side of the building to another shall not exceed one-half the story height at the location of embedment. This statement shall apply to the Immediate Occupancy Performance Level only.

7.1.2. Non-Structural Checklist

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Partitions

UNREINFORCED MASONRY: Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 10 feet in regions of low and moderate seismicity and 6 feet in regions of high seismicity.

Ceiling Systems

1. INTEGRATED CEILINGS: Integrated suspended ceilings at exits and corridors or weighing more than 2 lb/ft2 shall be laterally restrained with a minimum of 4 diagonal wires or rigid members attached to the structure above at a spacing of equal to or less than 12 ft.
2. LAY-IN TILES: Lay-in tiles used in ceiling panels located at exit ways and corridors shall be secured with clips.
3. SUPPORT: The integrated suspended ceiling system shall not be used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions.
4. SUSPENDED LATH AND PLASTER: Ceilings consisting of suspended lath and plaster or gypsum board shall be attached for each 10 square feet of area.

Light Fixtures

1. INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures.
2. EMERGENCY LIGHTING: Emergency lighting shall be anchored or braced to prevent falling or swaying during an earthquake.

Cladding and Glazing

1. CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be anchored to the exterior wall framing at a spacing equal to or less than 6 ft. for Life Safety and 4 ft. for Immediate Occupancy.
2. CLADDING ISOLATION: For moment frame buildings of steel or concrete, panel connections shall be detailed to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy.
3. MULITSTORY PANELS: For multi-storey panels attached at each floor level, the panels and connections shall be able to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy.
4. BEARING CONNECTIONS: Where bearing connections are required, there shall be a minimum of two bearing connections for each wall panel.
5. INSERTS: Where inserts are used in concrete connections, the inserts shall be anchored to reinforcing steel.
6. PANEL CONNECTIONS: Exterior cladding panels shall be anchored with a minimum of 2 connections for each wall panel for Life Safety and 4 connections for Immediate Occupancy.
7. DETERIORATION: There shall be no evidence of deterioration or corroding in any of the connection elements.
8. DAMAGE: There shall be no damage to exterior wall cladding.
9. GLAZING: Glazing in curtain walls and individual panes over 16 square feet in area, located up to a height of 10 feet above an exterior walking surface, shall be laminated annealed or heat strengthened safety glass that will remain in the frame when cracked.

Masonry Veneer

1. SHELF ANGLES: Masonry veneer shall be supported by shelf angles or other elements at each floor above the first floor.
2. TIES: Masonry veneer shall be connected to the back-up with corrosion-resistant ties. The ties shall have a spacing of equal to or less than 36" for Life Safety and 24" for Immediate Occupancy with a minimum of one tie for every 2-2/3 square feet.
3. WEAKENED PLANES: Masonry veneer shall be anchored to the back-up at locations of flashing.

Parapets, Cornices, Ornamentation And Appendages

1. URM PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices above the highest anchorage level with height-to-thickness ratios greater than 1.5 in regions of high seismicity and 2.5 in regions of moderate or low seismicity.
2. CANOPIES: Canopies located at building exits shall be anchored at a spacing 10 feet for Life Safety and 6 feet for Immediate Occupancy.

Masonry Chimneys

1. URM: No unreinforced masonry chimney shall extend above the roof surface more than twice the least dimension of the chimney.
2. MASONRY: Masonry chimneys shall be anchored to the floor and roof.

Stairs

1. URM WALLS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry.
2. STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure shall not rely on shallow anchors in concrete. Alternatively, the stair details shall be capable of accommodating the drift calculated using the Quick Check Procedure without inducing tension in the anchors.

Buildings Contents And Furnishing

1. EMERGENCY POWER: Equipment used as part of an emergency power system shall be mounted to maintain continued operation after an earthquake.
2. HEAVY EQUIPMENT: Equipment weighing over 20 lb that is attached to ceilings, walls, or other supports 4 ft. above the floor level shall be braced.

Piping

1. FIRE SUPPRESSION PIPING: Fire suppression piping shall be anchored and braced in accordance with *NFPA-13* (NFPA, 1996). This statement need not be evaluated for buildings in regions of moderate seismicity being evaluated to the Life Safety Performance Level.
2. FLEXIBLE COUPLINGS: Fluid, gas and fire suppression piping shall have flexible couplings. This statement need not be evaluated for buildings in regions of moderate seismicity being evaluated to the Life Safety Performance Level.

Hazardous Material Storage And Distribution

1. TOXIC SUBSTANCES: Toxic and hazardous substances stored in breakable containers shall be restrained from falling by latched doors, shelf lips, wires, or other methods.

7.2. Tier 2 Evaluation

A Tier 1 Evaluation shall be completed for all buildings prior to performing a Tier 2 Evaluation. A Full-Building Tier 2 analysis and evaluation of the adequacy of the lateral-force-resisting system shall be performed for all buildings designated.

For all other buildings, the design professional may choose to perform a Deficiency-Only Tier 2 evaluation that addresses only the deficiencies identified in Tier 1. Tier 2 procedures for further evaluation of Tier 1 deficiencies are identified by a section number in parentheses after each Tier 1 checklist evaluation statement.

A Tier 2 Evaluation shall include an analysis using one of the following linear methods: Linear Static Procedure, Linear Dynamic Procedure, or Special Procedure. If deficiencies are identified in a Tier 2 Evaluation, the design professional may perform a Tier 3 Evaluation in accordance with the requirements.

Four analysis procedures are provided in this section:

I. Linear Static Procedure (LSP),
II. Linear Dynamic Procedure (LDP),
III. Special Procedure, and
IV. Procedure for Non-structural Components.

All building structures, except unreinforced masonry (URM) bearing wall buildings with flexible diaphragms, shall be evaluated by either the Linear Static Procedure (LSP).

Unreinforced masonry (URM) bearing wall buildings with flexible diaphragms shall be evaluated in accordance with the requirements of the Special Procedure. The Linear Static or Linear Dynamic Procedure shall be performed as required by the Procedures.

7.2.1. Linear Static Procedure

The Linear Dynamic Procedure shall be used for buildings taller than 100 ft, buildings with mass, stiffness, or geometric irregularities.

- ✓ A mathematical building model shall be developed
- ✓ The pseudo lateral force shall be calculated
- ✓ The lateral forces shall be distributed vertically
- ✓ The building or component forces and displacements using linear, elastic analysis methods shall be calculated
- ✓ Diaphragm forces shall be calculated
- ✓ The component actions shall be compared

Pseudo Lateral Force

The fundamental period of vibration of the building shall be calculated as follows:

- ✓ For a one-story building with a single span flexible diaphragm, in accordance with Equation:

$$T = (0.1\Delta w + 0.078\Delta d)^{0.5}$$

where:

Δw and Δd are in-plane wall and diaphragm displacements in inches due to a lateral force equal to the weight tributary to diaphragm in the direction under consideration.

Vertical Distribution Of Seismic Force

The pseudo lateral force calculated as:

$$Fx = CvxV$$

$$Cvx = W_x h^x{}_k / \Sigma_{i=1}^{n} w_i h^{i}{}_k$$

where:
k = 1.0 for T < 0.5 second,
= 2.0 for T > 2.5 seconds,
Linear interpolation shall be used for
intermediate values of k;
Cvx= Vertical distribution factor,
V = Pseudo lateral force
wi = Portion of the total building weight W located on or assigned to floor level i,
wx= Portion of the total building weight W located on or assigned to floor level x,
hi = Height (ft) from the base to floor level i,
hx = Height (ft) from the base to floor level x.

Floor Diaphragm

The effects of inertial forces developed at the level under consideration and horizontal forces resulting from offsets in, or changes in stiffness of, the vertical lateral-force-resisting elements above and below the diaphragm shall be considered in the analyses. Forces resulting from offsets in, or changes in stiffness of, the vertical lateral-force-resisting elements shall be equal to the elastic forces without reduction, unless smaller forces can be justified by rational analysis.

$$Fpx = 1/CFi(wx/\Sigma^{n}{}_{i=1} * wi)$$

where:
Fpx = Total diaphragm force at level x,
Fi = Lateral load applied at floor level i defined
by Equation (4-2),
wi = Portion of the total building weight W
located or assigned to floor level i,
wx = Portion of the total building weight W
located or assigned to floor level x,
C = Modification Factor

7.2.2. Linear Dynamic Procedure

The Linear Dynamic Procedure shall be performed as follows:

- o Develop a mathematical building model

- Develop a response spectrum for the site in
- Perform a response spectrum analysis of the building
- Modify the actions and deformations in
- Compute diaphragm forces in accordance with
- Compute the component actions
- Compare the component actions

Modal responses shall be combined using the SRSS (square root sum of the squares) or CQC (complete quadratic combination) method to estimate the response quantities. The CQC shall be used when modal periods associated with motion in a given direction are within 25%. The number of modes considered in the response spectrum analysis shall be sufficient to capture at least 90% of the participating mass of the building in each of the building's principal horizontal axes.
Multidirectional excitation effects shall be considered. Alternatively, the SRSS method may be used to combine multidirectional effects. The CQC method shall not be used for combination of multidirectional effects.

Ground Motion Characterization
The seismic ground motions shall be characterized for use in the LDP by developing:

- A mapped response spectrum
- A site-specific response spectrum

Modification Of Demands:
With the exception of diaphragm actions and deformations, all actions and deformations calculated using the Linear Dynamic Procedure shall be multiplied by the modification factor.

Building Type[1]	Number of Stories			
	1	2	3	≥4
Wood (W1, W1A, W2) Moment Frame (S1, S3, C1, PC2A)	1.3	1.1	1.0	1.0
Shear Wall (S4, S5, C2, C3, PC1A, PC2, RM2, URMA) Braced Frame (S2)	1.4	1.2	1.1	1.0
Unreinforced Masonry (URM) Flexible Diaphragms (S1A, S2A, S5A, C2A, C3A, PC1, RM1)	1.0	1.0	1.0	1.0

Table 1: Modification Factor

Floor Diaphragms
Floor diaphragms shall be analysed for (1) the seismic forces calculated by dynamic analysis, and (2) the horizontal forces resulting from offsets in, or changes in stiffness of, the vertical seismic framing elements above and below the diaphragm. The seismic forces calculated by dynamic analysis shall not be less than 85% of the forces calculated. Forces resulting from offsets in, or changes in stiffness of, the vertical lateral-force-resisting elements shall be taken to be equal to the elastic forces without reduction, unless smaller forces can be justified by rational analysis.

7.2.3. Special Procedure
Unreinforced masonry bearing wall buildings with flexible diaphragms being evaluated to the Life Safety Performance Level shall be evaluated in accordance with the requirements of this section.
The evaluation requirements shall met prior to conducting this special procedure. This special procedure shall apply to unreinforced masonry bearing wall buildings with the following characteristics:

- Flexible diaphragms at all levels above the base of the structure;
- A minimum of two lines of walls in each principal direction, except for single-story buildings with an open front on one side.

- A Tier 3 evaluation shall be conducted for buildings not meeting the requirements of this section.

7.3. Tier 3 Evaluation / Detail Evaluation Phase

A Tier 3 Evaluation shall be performed either for the entire building after those elements identified to be deficient in a Tier 1 and/or Tier 2 Evaluation.

❖ ***Available Procedures***

A Tier 3 Evaluation shall be performed using one of the two following procedures:

7.3.1. Provision For Seismic Rehabilitation Design:

A component-based evaluation procedure developed for seismic rehabilitation of existing buildings shall be used for a Tier 3 Evaluation. Acceptable analysis procedures for such a detailed evaluation include linear and nonlinear methods for static or dynamic analysis of buildings. Acceptance criteria for such detailed evaluations for various performance levels are based on stiffness, strength, and ductility characteristics of elements and components derived from laboratory tests and analytical studies. The more accurate analysis method and more realistic acceptance criteria developed specifically for rehabilitation of existing buildings shall constitute the detailed evaluation phase. Such a component-based detailed evaluation procedure shall be used in accordance with the authority having jurisdiction.

Force levels used for analysis in provisions for seismic rehabilitation of existing buildings shall be multiplied by 0.75 when used in a Tier 3 Evaluation. If a linear analysis method is selected, the analysis shall implicitly or explicitly recognize nonlinear response.

7.3.2. Provision For Design Of New Building

Well-established provisions for the design of new buildings approved by the authority having jurisdiction shall be used to perform a Tier 3 Evaluation of an existing building. Acceptable provisions for such a detailed evaluation, Earthquake Loads, Minimum *Design Loads for Buildings and Other Structures (ASCE 7-95).* Such a detailed evaluation shall be performed in accordance with the authority having jurisdiction.

Force levels used for analysis in provisions for seismic design of new buildings shall be multiplied by 0.75 when used in a Tier 3 Evaluation. If a linear analysis method is selected, the analysis shall implicitly or explicitly recognize nonlinear response.

❖ **Selection of Detailed Procedures**

Buildings with one or more of the following characteristics shall be evaluated using linear dynamic or nonlinear static or dynamic analysis methods:

- Height exceeds 100 feet;
- The ratio of the building's horizontal dimension at any story exceeds 1.4 times the

horizontal dimension at an adjacent story (excluding penthouses);

- The calculated drift along the side of any story, where the diaphragm above is not flexible, is more than 150% of the average story drift (torsional stiffness irregularity)
- The average drift in any story (excluding penthouses) is more than 150% of the drift of the story above or below (vertical stiffness irregularity);
- The lateral-force-resisting system is non-orthogonal.

8. SCREENING PROCESS

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

HIGH Seismicity

Address: ______ Zip ______
Other Identifiers ______
No. Stories ______ Year Built ______
Screener ______ Date ______
Total Floor Area (sq. ft.) ______
Building Name ______
Use ______

Scale:

PHOTOGRAPH

OCCUPANCY			SOIL		TYPE						FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+		A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, S

COMMENTS

Detailed Evaluation Required YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Fig 8 : High Seismicity Data Collection Form Format

9.OBSERVATION`

From the screening process and checklist provided stepwise Evaluation was done to nearly 80 different types of structures present at Budhanilkantha , the different structures included were:

I. Commercial Building:

There are lots of recently constructed commercial buildings at Budhanilkantha area which are designed according to Bye Laws and analysed properly. Hence those structures which are well designed and constructed are safe against seismic forces.

Still there are some commercial buildings which are built long back possess a great threat of seismic forces. The evaluation of such building needed further screening.

II. Public Buildings:

Public buildings include Schools, Government offices, hospitals etc. I personally had screening on different schools where the density of student per building was found to be very high. Few schools were found to be seismically safe where some were found to be vulnerable.

Fig 9 : School at Budhanilkantha

III. Residential Buildings:

It included both recent constructed houses as well as typical existing buildings. The types of it are:

- RCC frame structure
- Brick Masonry in Cement Mortar

There seemed to be a lot of variation on construction practises on Residential Building from those of Designed one and on Field. Buildings which were constructed few years back are not properly designed and analysed. These buildings suffer from lot of Plan and Vertical irregularities. They also posses soft storey problem leading to liquefaction and settlement.

Regardless of it, those which are recently constructed are properly designed against seismic forces. But the problem lies on proper construction practise. Whereas there still are some residential buildings which are well designed and well executed on construction practices.

The common problem is same on Both the types of buildings RCC and BMC.

Fig 9: Recently Constructed House at Budhanilkantha

IV. Historical Monuments:

Budhanilkantha is famous for historic Bishnu Temple. Recent earthquake has severe destruction on the structures inside temple premises. Similarly, there are some other Religious places nearby which are vulnerable and some are under retrofitting and restoration Process.

10. CONCLUSION

The research on the topic "Probabilistic Seismic Hazard and risk Analysis" on Budhanilkantha region at Kathmandu valley made me draw following conclusions:

Kathmandu is a seismically active region. It is surrounded with number of hills alongside and hence has got a bowl shape. Also, Budhanilkantha being at hill side of Shivapuri hill is very prone to earthquake.

From screening of number of houses using FEMA model following Probabilistic Seismic Hazard on topics are identified:

I. Hazard on Life:

Since there, it was found to be number of residential and commercial buildings at Budhanilkantha area. Out of 80 structures which were evaluated, those which are newly constructed under well design and construction practise are safe and have no threat on life.

Where there are also typical old residential buildings which are constructed years ago. They were found vulnerable with wrong construction practise and presence of plan and vertical irregularities.

Having these vulnerable structures, they are great threat to human life. Since Budhanilkantha area is habitat of lot of Local residents as well as people from outside valley residing for different purposes. So, the risk of life is more on such buildings.

Along with I have found new residential buildings which have bee well designed but vulnerable due to wrong construction practices. The reason for this is lack of skilled manpower which includes mason and lack of training on skilled people.

Hence new buildings of certain percentage are also found to have threat on life.

II. Hazard on Property:

Above discussed hazard on life is directly associate with property and assets of individual. Seismic activity does not directly involve in life taking action it happens with destroying structure, property which then takes many lives.

So, hazard on property is always a first during earthquake. The evaluation on Budhanilkantha area on different buildings have given mere idea about hazard on property on this region is considerably high as those structure which are old as those new ones with construction malpractices.

Regarding residential and commercial buildings there are many civil works which are of great importance and are susceptible of earthquake.

III. Hazard on Natural Resources:

This area is source of water since it contains many streams and lies along hillside. So, any high GPA earthquake may cause the source to dislocate and also may cause natural calamites causing landslides.

Hence there seems to be risk on natural resources as well by any kind of seismic activity.

IV. Hazard on Ground Profile:

Budhanilkantha lies on partial slope and plane area. Hence chance of liquefaction and settlement is more on plane area where chance of sliding and overturning is more on slope area.

Because of change on ground profile it directly affects on property and life.

These are various hazards which are observed on Budhanilkantha area. These hazards can be minimised but risk of seismic activity cannot be minimised. Hence proper and safe construction, Knowledge of safety evacuation programme and coordination on each engineering and non-engineering aspect is must.

11. RECOMMENDATIONS

This thesis is carried out in limited time with limited resource. The used process in this thesis is based on FEMA 310 model. Most of the observation done here are based on visual and personal infographic system. Since the third-tier evaluation and analysis process is very much complex to carry out for number of buildings it could not be carried out.

Hence for this thesis to continue further, third tier evaluation can be done by following pushover analysis and finding time history period and safety of structures. Such adopted if gives much more precision on results but needs very detail information of architectural and structural components.

For the analysis of pushover software's like SAP2000, Etabs can be used.

12. PHOTOGRAPHS

Fig: Part of Budhanilkantha area

Fig: Part of Budhanilkantha Area

Fig: House under construction at Budhanilkantha

Fig: House under construction

Fig: BMC Houses

Fig: Hybrid Structure

Fig: BMC House with Truss

Fig: Recently constructed House

Fig: Well Designed House and Construction Practise

Fig: Foundation and Column Layout

Fig: Construction Malpractice

Fig: Plan Irregularity

Fig: Screening at Public School

Fig: Screening at School

Fig: Evaluation of School

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