CAPACITY BUILDING WORKSOP FOR CLIMATE CHANGE ADAPTATION
IN THE REPUBLIC OF MAURITIUS, PORT LOUIS, AUGUST 9-10, 2012
Jaime F. Argudo, Ph.D., P.E . (Tx) – UNOPS CONSULTANT

LAND USE ZONING AND BUILDING CODE REGULATIONS FOR ~~EARTHQUAKE SAFETY AND DAMAGE MITIGATION~~ SAFE AND DURABLE CONSTRUCTION IN ENVIRONMENTS EXPOSED TO NATURAL AND HUMAN-MADE HAZARDS

Argudo and Associates
Structural & Geotechnical Engineering
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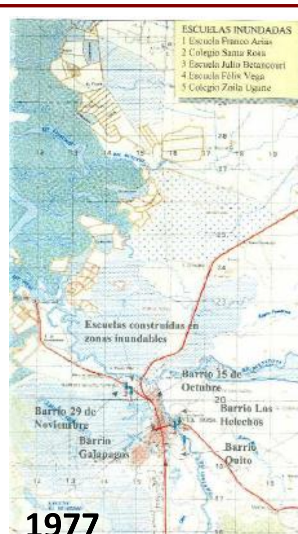
- Environmental + Ecology 70s
- Sustainable Development 80s
- IDNDR 90s
- ISDR + IPCC (GW) + GREEN CONST 00s
- CCA + ? 10s STILL DOING SAME



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El Niño
1998-1999
Ecuador

SUSTAINABLE DEVELOPMENT: To meet the needs of the present generation without compromising the ability of future generations to meet their own needs

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ADAPTATION TO CLIMATE CHANGE: To develop resilience to aggravated extreme natural and human made hazards

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IN THE FRAMEWORK OF:

- SUSTAINABLE DEVELOPMENT
- DISASTER RISK AND MITIGATION
- CLIMATE CHANGE ADAPTATION AND MITIGATION
- STATE-OF-THE-ART METHODS AND TECHNIQUES FOR BUILDING DESIGN AND CONSTRUCTION (ENERGY EFFICIENCY, GREEN BUILDINGS, PERFORMANCE BASED DESINGS, ETC.)

"LAND USE ZONING REGULATIONS AND BUILDING CONSTRUCTION CODE SPECIFICATIONS" are based on comprehensive assessments that have to consider the effects of multiple natural and human-made hazards on: the communities' safety, health and wellbeing; the built infrastructure; and the environment (Jaime Argudo)

Disaster Risk Reduction (DDR) and Climate Change Mitigation and Adaptation (CCMA) share common goals. Both fields aim to reduce the vulnerability of communities and achieve sustainable development. (ISDR)

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THE RADIUS PROJECT IN GUAYAQUIL - ECUADOR

Jaime F. Argudo, Ph.D, P.E. (Tx)
Universidad Católica de Santiago de Guayaquil

http://jaimeargudo.com/radius-project/
http://www.geohaz.org/radius

MUNICIPALIDAD DE GUAYAQUIL
DIRECCION DEL PLAN DE DESARROLLO URBANO CANTONAL
IDNDR—N.N.U.U.
1990–2000
DECENIO INTERNACIONAL PARA LA REDUCCION DE DESASTRES NATURALES
UNIVERSIDAD CATÓLICA DE SANTIAGO DE GUAYAQUIL
INSTITUTO DE INVESTIGACIÓN Y DESARROLLO DE INGENIERIA
GeoHazards International

GUAYAQUIL CITY

- 2.5 millions inhabitants

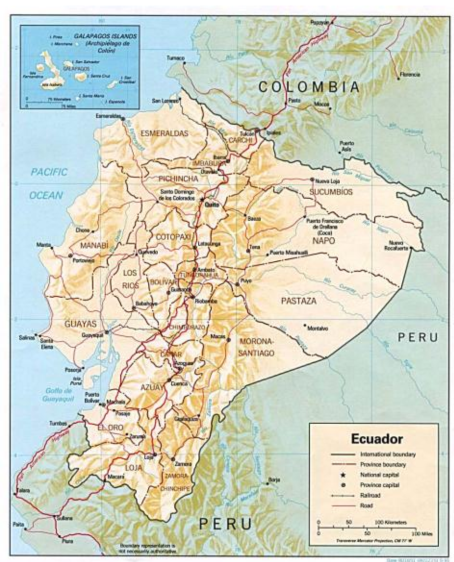
  33,825 hectares

  3.5% population growth

GUAYAQUIL CITY

- Main port, industrial and commercial city of Ecuador

  20% gross national product of whole country



The city is under a big rehabilitation project, to preserve key historical buildings and neighborhoods



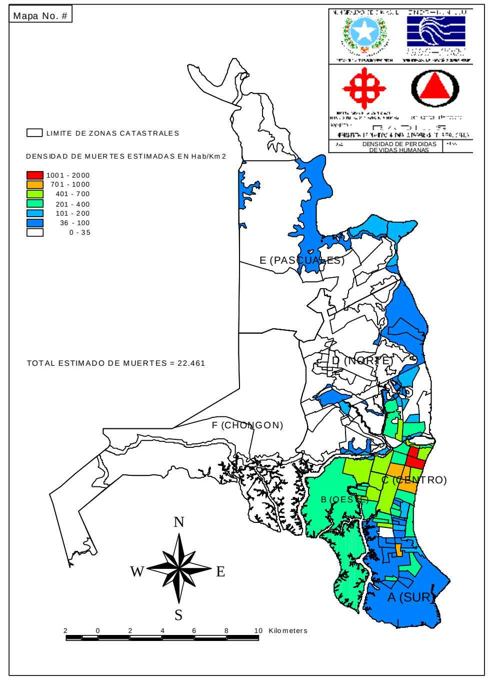

THE OBJECTIVES OF RADIUS

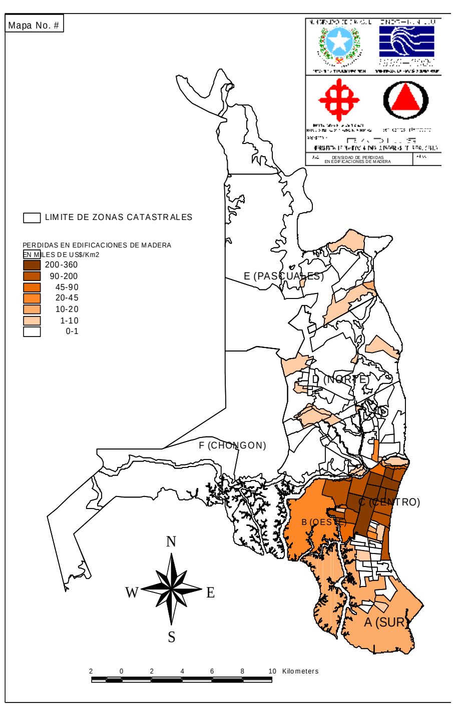
- To evaluate the seismic risk and to develop an hypothetical earthquake scenario of damage
- To prepare an Action Plan based upon the results of the seismic risk evaluation
- To increase public awareness in citizens and governmental authorities about seismic risk
- To initiate an institutionalization process to support mitigation efforts and the seismic risk management

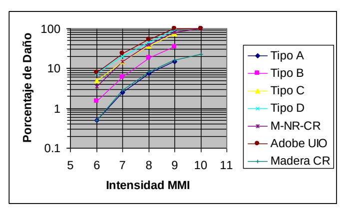
THE SEISMIC RISK

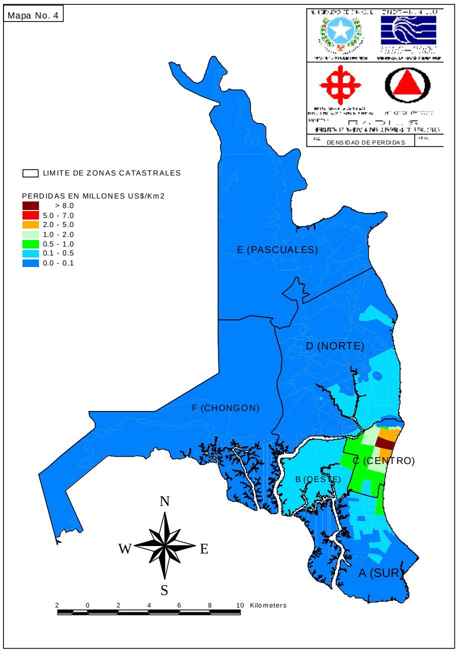
- **53% probability that within the next 50 years an earthquake may cause MMI = VIII in the city. *In the worst-case scenario,* such MMI = VIII correlates with 22,461 casualties and 90,114 injures**

- **For such earthquake scenario, economic losses were estimated in excess of US$ 1,000 millions**

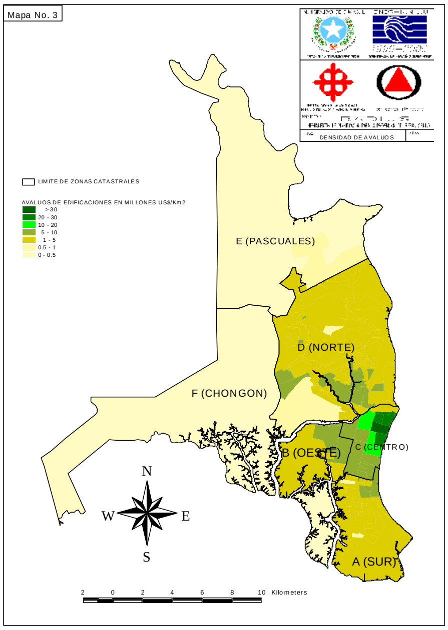








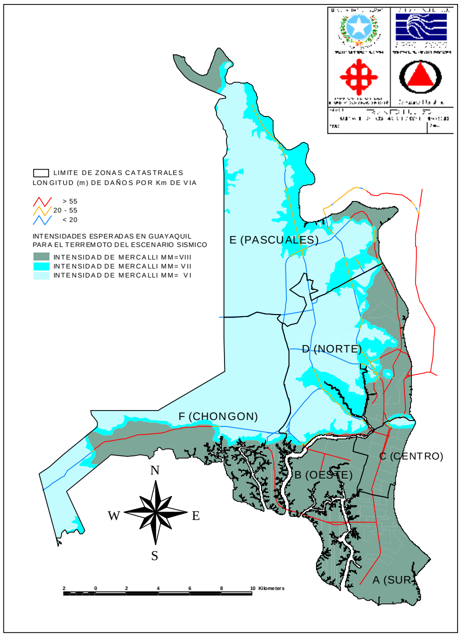
- High construction density
- High vulnerability due to great amount of old buildings and infrastructure built without seismic design provisions
- Great value of buildings, infrastructure and equipment used in commercial and financial activities; and
- High population density during commercial hours.



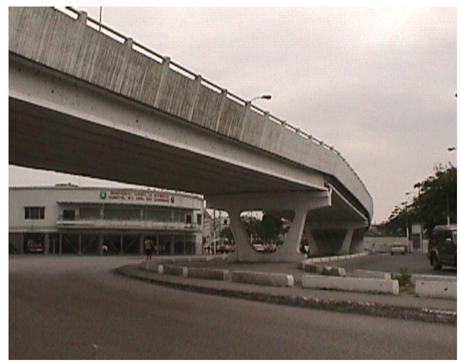
EVALUATION OF CRITICAL FACILITIES

- **75% hospitals non-operational after the earthquake**
- **The provision of temporary or permanent shelter for those affected (up to 20.000) would be very slow**

- **10% of school buildings could be severely damaged**
- **There might be a partial and significant suspension of utilities during the first week following the earthquake**



- **25% bridges could be affected due to lost in strength in pre-stressing strands, corrosion of reinforcement, or inadequate seismic design (old structures)**



THE ACTION PLAN

- **Evaluation and strengthening of buildings and dangerous infrastructure**
- **Training of personnel for specialized rescue operations, paramedics, etc**
- **Creation of a technical unit for disaster preparedness and management in the municipal government**
- **Preparedness of the community through campaigns of prevention and mitigation**

THE ACTION PLAN

- Emergency planning for adequate response and recovery of utilities and critical facilities
- Maintenance, modernization and rehabilitation of equipment and services in emergency systems
- Study and monitoring of geological and seismic hazards
- Evaluation of critical urban areas and soil use control
- Preparation of a Seismic Design Manual and construction code enforcement

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ASCE 31-03

Seismic Evaluation of Existing Buildings

American Society of Civil Engineers / 01-Jan-2003 / 444 pages

ISBN: 0784406707

Scope:

Seismic Evaluation of Existing Buildings (ASCE 31-03), provides a three-tiered process for seismic evaluation of existing buildings in any level of seismicity. Buildings are evaluated to either the Life Safety or Immediate Occupancy Performance Level.
This standard is intended to serve as a nationally applicable tool for design professionals, code officials, and building owners looking to seismically evaluate existing buildings. A major portion is dedicated to instructing the evaluating design professional on how to determine if a building is adequately designed and constructed to resist seismic forces. The design of mitigation measures is not addressed in this standard. ASCE 31-03 is intended to replace FEMA 310, Handbook for Seismic Evaluation of Buildings -- A Prestandard (FEMA, 1998). All aspects of building performance are considered and defined in terms of structural, nonstructural, and foundation/geologic hazard issues. This standard was written to: reflect advancements in technology; incorporate the experience of design professionals; incorporate lessons learned during recent earthquakes; be compatible with FEMA 356, Prestandard and Commentary for the Seismic Rehabilitation of Buildings (FEMA, 2000c); be suitable for adoption in building codes and contracts; be nationally applicable; and provide evaluation techniques.

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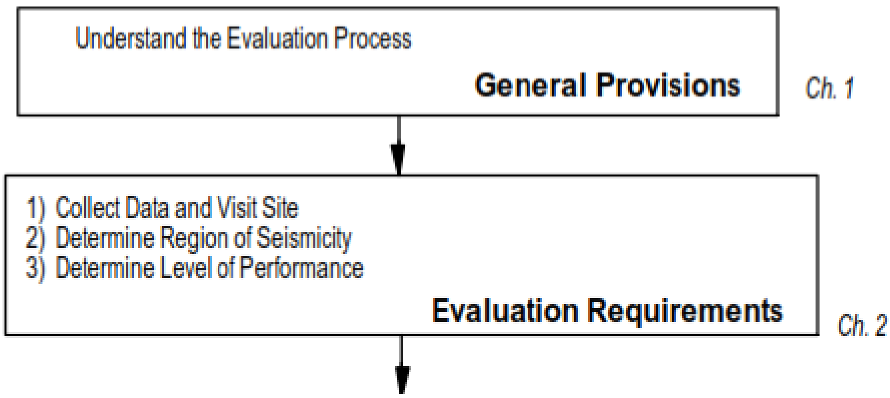
CONFERENCIA: EVALUACIÓN Y REHABILITACIÓN SÍSMICA DE ESTRUCTURAS ESENCIALES EN CONDICIÓN DE RIESGO (SEMINARIO FEPOL 2012)
Por: Jaime F. Argudo, Ph.D., P.E . (Tx)



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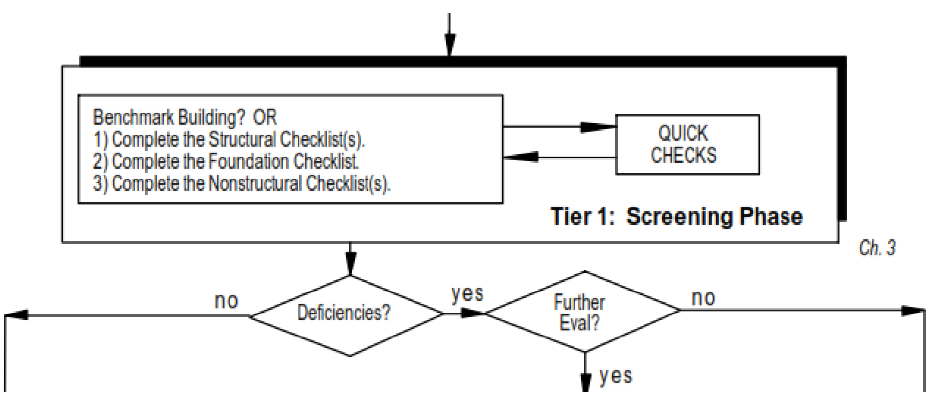

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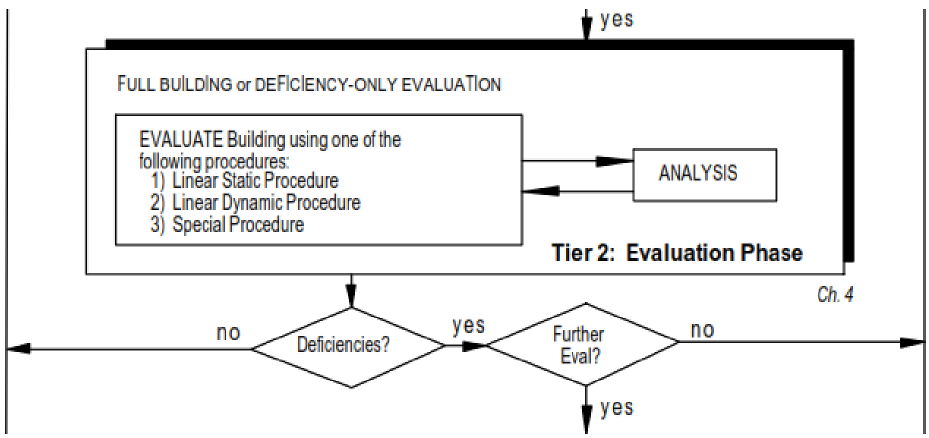

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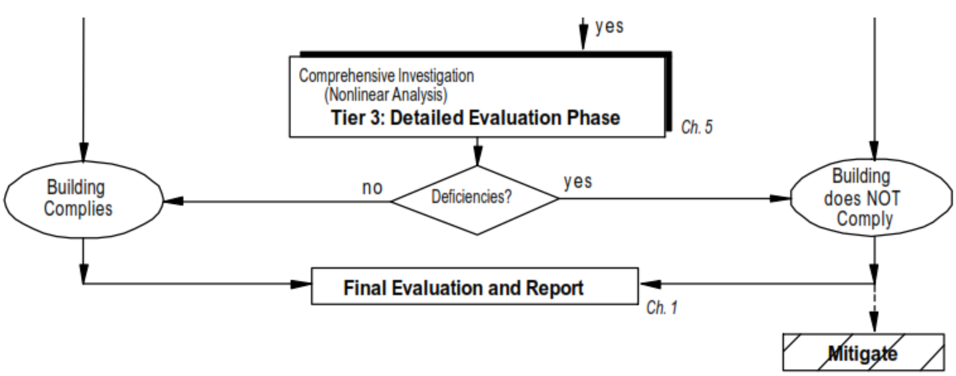

Figure 1-1. Evaluation Process

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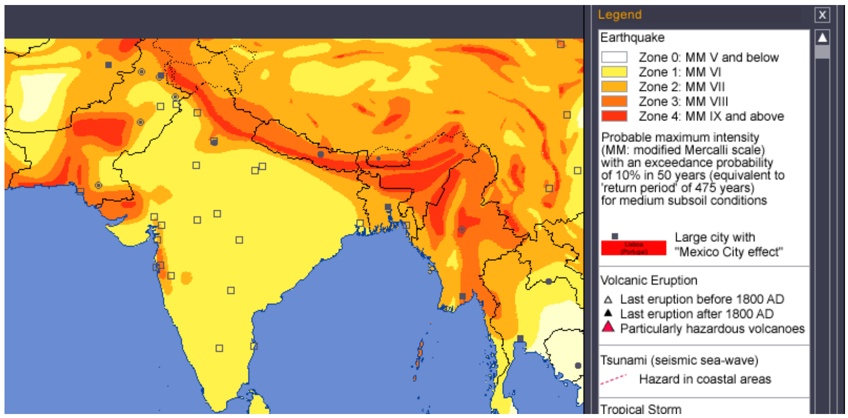
Structural Assessment of Hospitals in Kathmandu Valley

Jaime Argudo
Structural Engineer, WHO
Emergency and Humanitarian Action

APPROACH

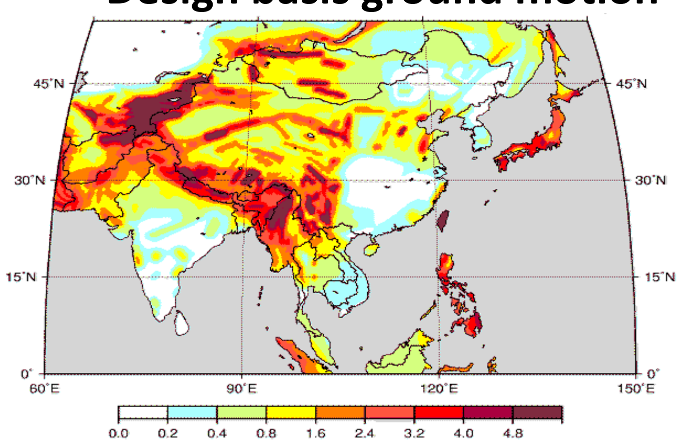
- Seismic hazard definition
- Soil and site effects evaluation
- Structural vulnerability factors ID
- Building design criteria ID
- Earthquake performance evaluation
- Lifeline systems main features ID
- Hospital-infrastructure reliability assessment

Seismic-Hazard Zoning Map



Source: WORLD OF NATURAL HAZARDS MUNICH RE. GROUP, 2001.

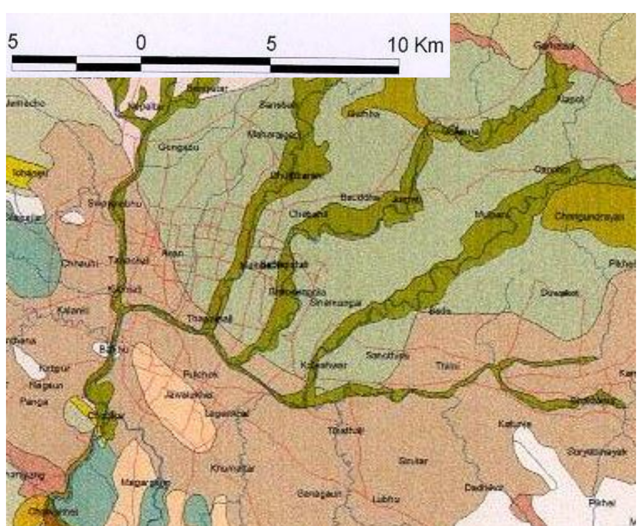
Design basis ground motion

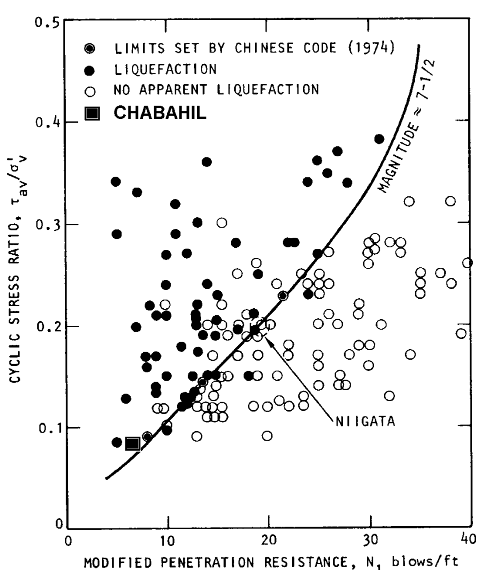


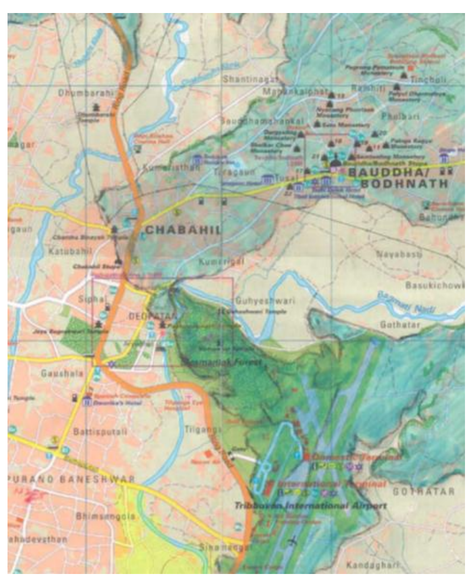
Source: GLOBAL SEISMIC HAZARD ASSESSMENT PROGRAM IN CONTINENTAL ASIA (GSHAP). International Lithosphere Program (ILP), 1999.

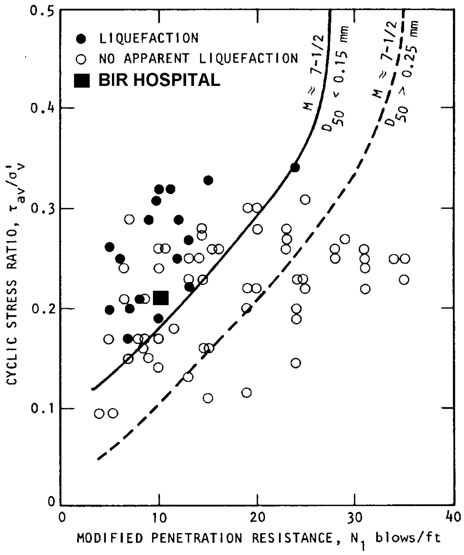
Soil Liquefaction

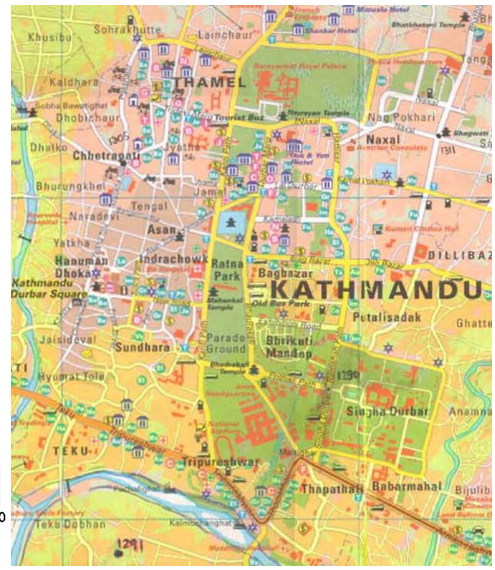
Geolo-gical Map

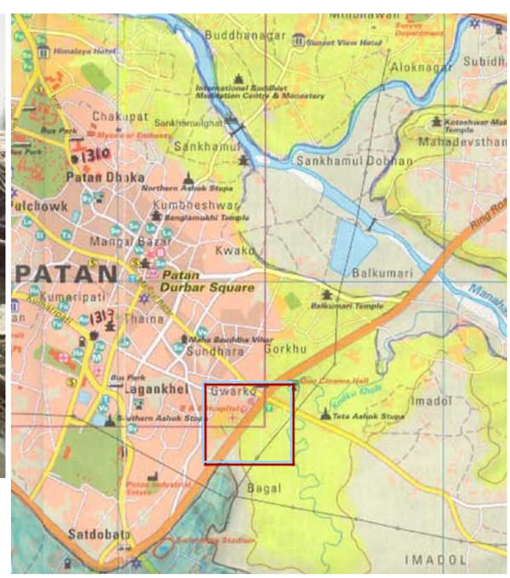


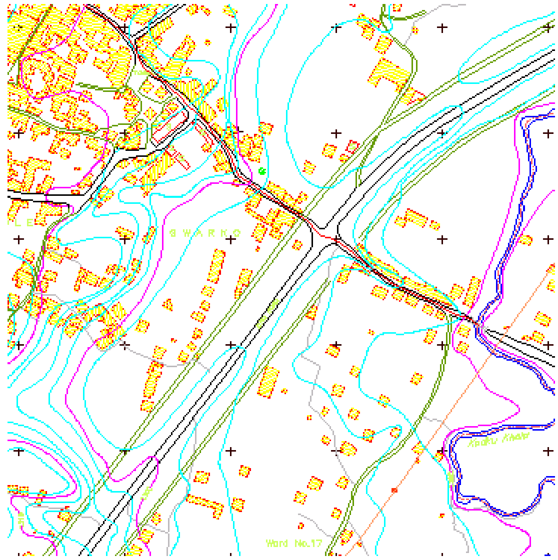

LIMITS SET BY CHINESE CODE (1974)
LIQUEFACTION
NO APPARENT LIQUEFACTION
CHABAHIL
MAGNITUDE ≈ 7-1/2
NIIGATA
CYCLIC STRESS RATIO, τ_{av}/σ'_v
MODIFIED PENETRATION RESISTANCE, N_1 blows/ft
0
0.1
0.2
0.3
0.4
0.5
0
10
20
30
40


CHABAHIL
BAUDDHA/
BODHNATH
PURANO BANESHWAR
GOTHATAR
Tribhuvan International Airport

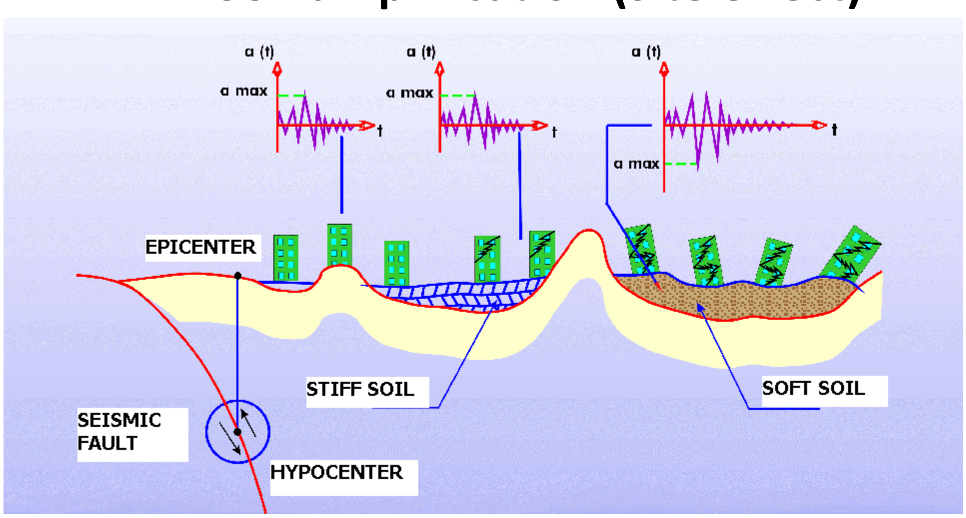

LIQUEFACTION
NO APPARENT LIQUEFACTION
BIR HOSPITAL
M ≈ 7-1/2
D50 < 0.15 mm
M ≈ 7-1/2
D50 > 0.25 mm
CYCLIC STRESS RATIO, τav/σ'v
MODIFIED PENETRATION RESISTANCE, N1 blows/ft
0
0.1
0.2
0.3
0.4
0.5
10
20
30
40

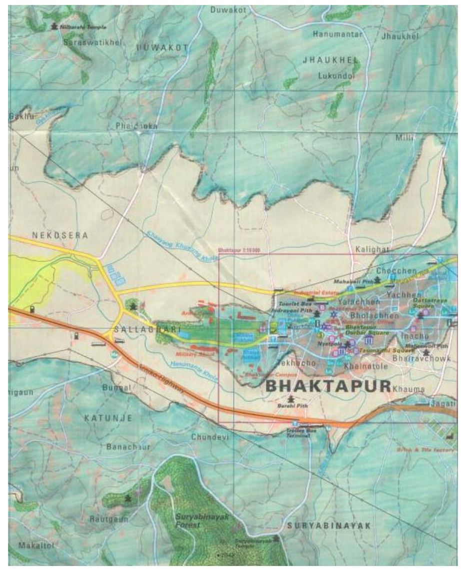

THAMEL
KATHMANDU
Lainchaur
Sohrakhutte
Khusibu
Kaldhara
Dhobichaur
Dhalko
Chhetrapati
Bhurungkhel
Naradevi
Tengal
Asan
Yatkha
Hanuman Dhoka
Kathmandu Durbar Square
Indrachowk
Ratna Park
Bagbazar
Naxal
Nag Pokhari
Jamal
Putalisadak
Jaisidewal
Sundhara
Parade Ground
Bhrikuti Mandap
Hyumat Tole
Singha Durbar
Anamnagar
TEKU
Tripureshwar
Thapathali
Babarmahal
Teku Dobhan
DILLIBAZAR


Buddhanagar
Aloknagar
Chakupat
Sankhamul
Sankhamul Dobhan
Patan Dhoka
Kumbheshwar
Mangal Bazar
PATAN
Patan Durbar Square
Kwako
Balkumari
Kumaripati
Thaina
Sundhara
Gorkhu
Lagankhel
Gwarko
Imadol
Bagal
Satdobato
IMADOL
Mahadevsthan

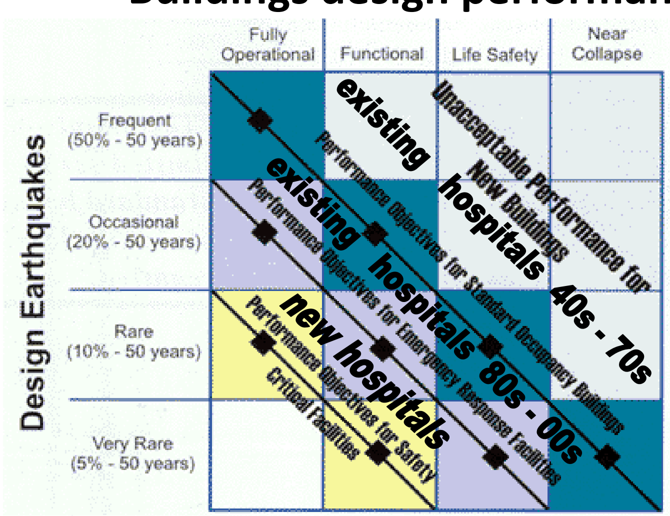


Soil amplification (site effect)





Buildings design performance



Source: Structural Engineers Association of California (SEAOC) – Vision 2000, 1995.

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US ICC (International Code Council) Performance Code - 2000

TABLE 303.3
MAXIMUM LEVEL OF DAMAGE TO BE TOLERATED BASED ON PERFORMANCE GROUPS AND DESIGN EVENT MAGNITUDES

MAGNITUDE OF DESIGN EVENT (INCREASING MAGNITUDE OF EVENT ↑)	INCREASING LEVEL OF PERFORMANCE →→→ PERFORMANCE GROUPS: Performance Group I	Performance Group II	Performance Group III	Performance Group IV
VERY LARGE (Very Rare)	SEVERE	SEVERE	HIGH	MODERATE
LARGE (Rare)	SEVERE	HIGH	MODERATE	MILD
MEDIUM (Less Frequent)	HIGH	MODERATE	MILD	MILD
SMALL (Frequent)	MODERATE	MILD	MILD	MILD

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US ICC (International Code Council) Performance Code - 2000

CHAPTER 3

DESIGN PERFORMANCE LEVELS

303.4 There are four performance groups (PG), identified as I, II, III and IV.

303.4.1 Performance Group I. The minimum design performance level with which all buildings or facilities posing a low risk to human life, should the buildings or facilities fail, must comply.

303.4.2 Performance Group II. The minimum design performance level with which all buildings or facilities subject to this code, except those classified as PG I, PG III or PG IV, must comply.

303.4.3 Performance Group III. The minimum design performance level with which buildings or facilities of an increased level of societal benefit or importance must comply.

303.4.4 Performance Group IV. The minimum design performance level with which buildings or facilities that present an unusually high risk or which are deemed essential facilities must comply.

CHAPTER 5

STABILITY

SECTION 501 STRUCTURAL FORCES

501.3.4 Structures, or portions thereof, shall be designed and constructed taking into account all expected loads, and combination of loads, associated with the event(s) magnitude(s) that would affect their performance, including, but not limited to:

11. Earthquake loads (mean return period)

Small: 25 years
Medium: 72 years
Large: 475 years
Very Large: 2,475 years

Building	Performance Group
Farms - warehouses	Group I
Apartment Buildings	Group II
Schools	Group III
Hospitals, Fire Stations	Group IV

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Methodology

- To assess infrastructure reliability

  Qualitative method (15 hospitals):

  - Expert criteria - Check lists
  - Drawing plans review
  - Ground-floor-columns stress-checking

- To reduce structural vulnerability

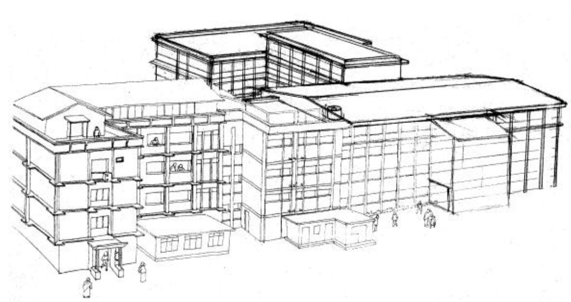
  Quantitative method (BIR hospital):

  - Detailed numerical analysis
  - Retrofitting structural pre-design

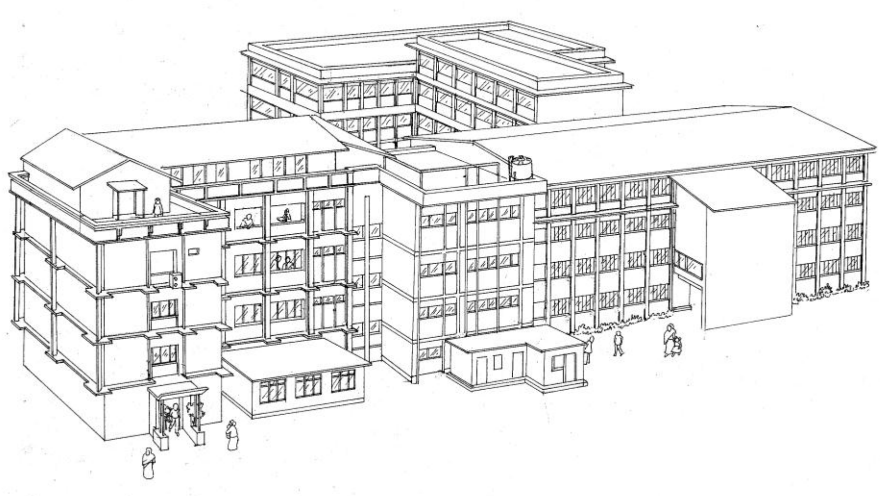
Police hospital

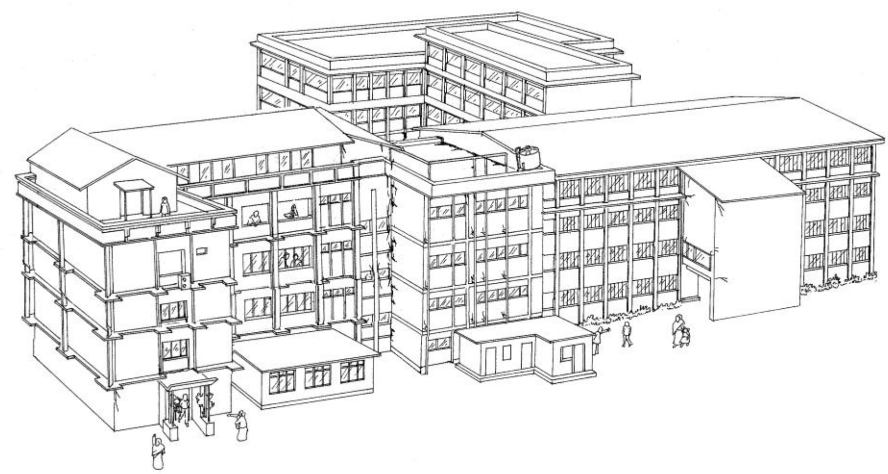
23cmx23cm columns from bottom to top. Should be 40x40(1st)- 30x30(2nd)- 23x23(3rd)

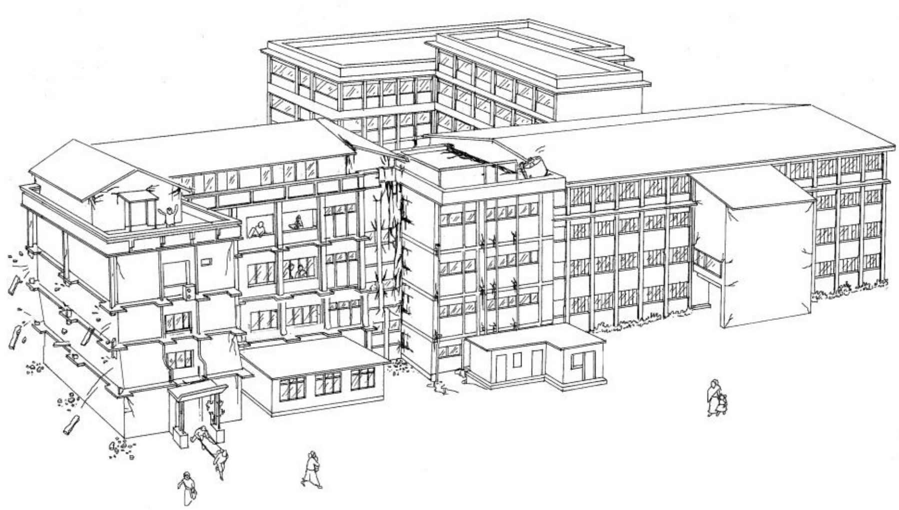

BIR hospital

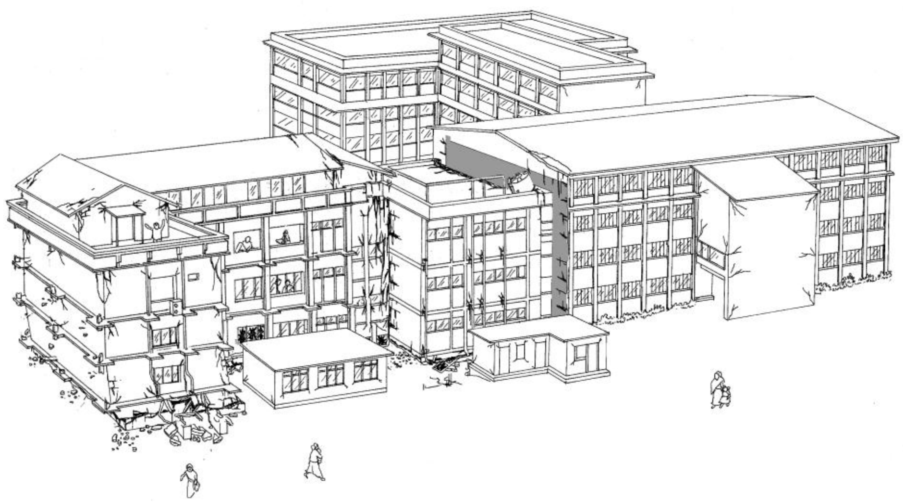


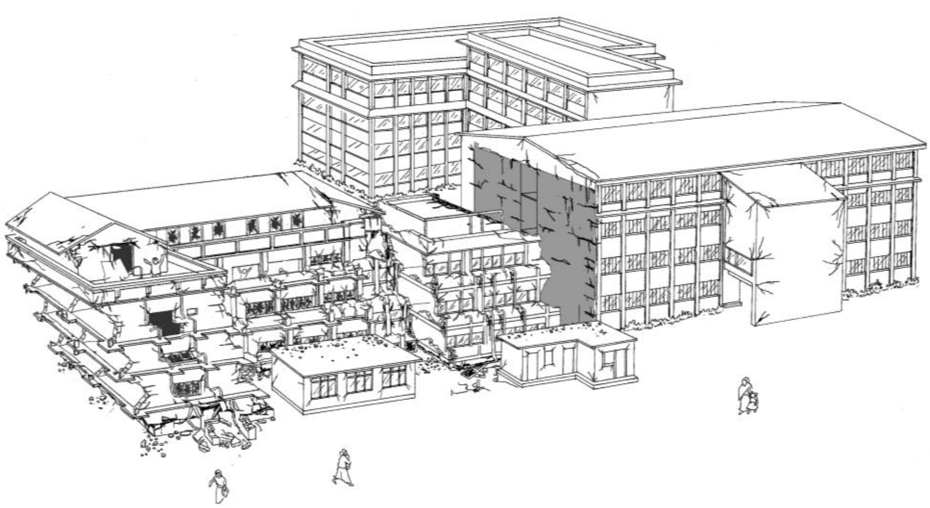
Retrofitting is been recommended

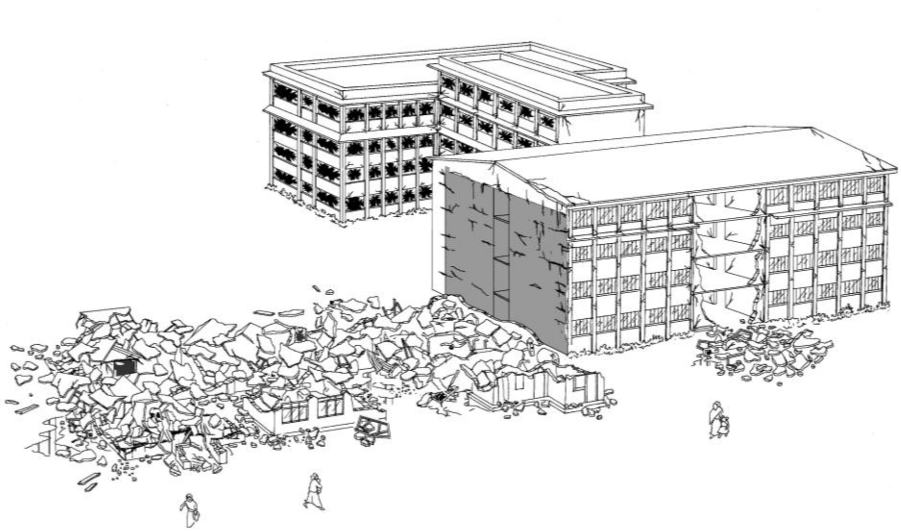




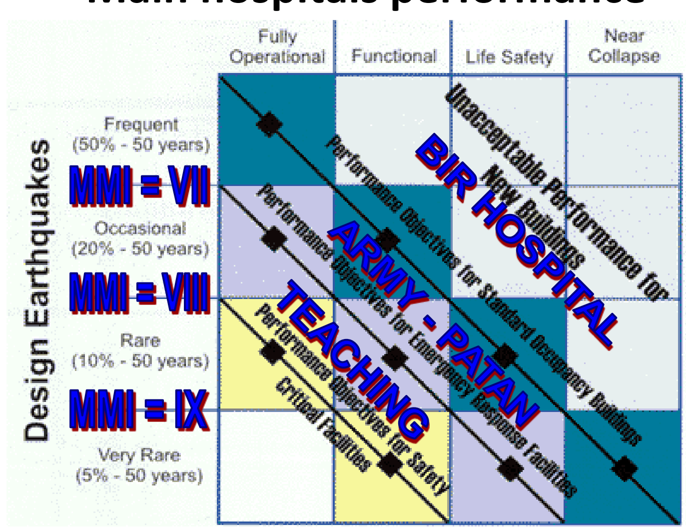




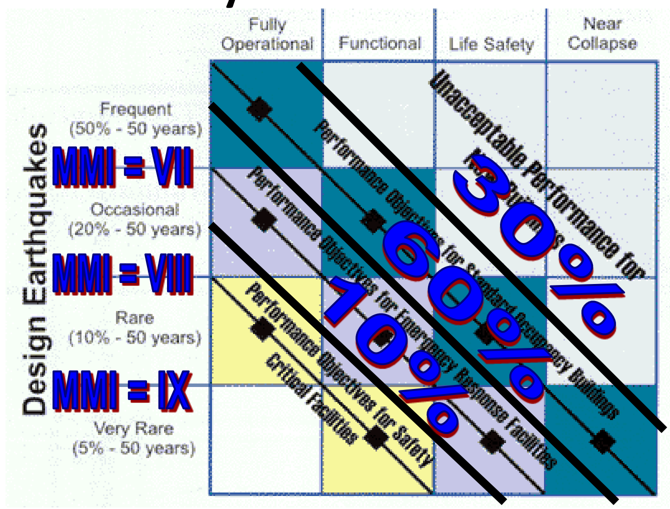




Main hospitals performance



Reliability assessment PuHKV



Main Recommendations

- Design forces need to be increased from 50% to 100% in case of RC bldg.

  Code specifications must be reviewed
- Improve columns design.

  Avoid first-weak story.
- Improve materials quality
- Prefer low rise structures of less complexity in architectural plans. When high rise structures are used, prefer dual systems
- Improve design and construction of joints.

Future steps recommended

- Retrofitting of BIR and Police hospitals
- Conduct a detail quantitative analysis of Patan and Army hospitals
- Evaluate Non-structural vulnerability of Teaching, Patan and Army hospitals
- Construct new hospital at Bhaktapur and set up nev emergency facilities.
- Detailed qualitative assessment of Kanti, Maternity, Teku and B&B hospitals including soil liquefaction analysis.

FINAL REVIEW ON THE MALDIVES NATIONAL BUILDING CODE (MNBC-2008) AND ITS COMPLIANCE DOCUMENTS

By

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Structural Engineer
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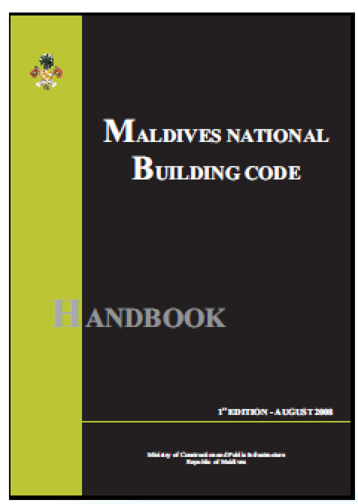

Review of the MNBC-2008 and its Compliance Documents
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Code Philosophy

The Maldivian Building Code is a **Performance Based Code**, aimed to provide "**flexibility**" in "**design**" and "**construction**" practices for:

1. Implementing future changes to the **"Compliance Documents"** without changing the **"Building Code Document"** to accommodate innovative material technologies, design and construction practices.

2. Allowing the use of design specifications, construction methods and material technologies from elsewhere, as "**alternative**" solutions and verification methods to "**acceptable**" solutions and verification methods" contained in the Compliance Documents.

Compliance Documents

1. Contain the prescriptive specifications from the British and New Zeeland's Building Codes and Material Standards that have been adopted or may be adapted for the Maldivian Building Code.

   Although printed separately, they are a **constitutive** and **mandatory** part of the Maldivian Building Code and its use should be enforced by incorporating references to applicable Compliance Documents in each of the Building Code chapters.

2. Specifications in Compliance Documents are named as **Acceptable Solutions** and **Verification Methods** that, if used, will result in compliance with the Maldivian Building Code.

   They can be homologated by **Alternative** Solutions or Verification Methods that must meet or exceed the requirements for the minimum level of safety and building performance defined in the Maldivian Building Code.

Performance Objectives, Functional Requirements and Performance Requirements

The Building Code uses Performance Objectives, Functional Requirements and Performance Requirements to define the minimum level of safety and building performance set for compliance in the Republic of Maldives.

Performance Objectives and Functional Requirements are stated qualitatively, using words such as "sufficient, acceptable, adequate, etc." Also, many Performance Requirements are presently stated qualitatively, but in as much as possible, they should be changed to quantitative statements to facilitate future code enforcement and use of alternative solutions and verifications methods.

The performance requirements shall define in measurable terms, the minimum level of safety and building performance that an alternative solution or verification method must meet or exceed.

Example 1 (Qualitative/Quantitative Code Requirements)

Performance Objective	Performance Requirement
D.1.1 (c) Ensure that people with disabilities are able to enter and carry out normal activities and functions within buildings. Limits of Application: Shall only apply to those buildings which serve the public, buildings designated for Disabled Persons' use and to buildings where accessibility is required by any other Act. **Functional Requirement** D1.2.1 Buildings shall be provided with **reasonable** and **adequate** access to enable safe and easy movement of people.	D1.3.2 At least <u>one</u> access route shall have features to enable people with disabilities to: (a) Approach the building from the street boundary or, where required to be provided , the building car park, (b) Have access to the internal space served by the principal access, and (c) Have access to and within those spaces where they may be expected to work or visit, or which contain facilities for personal hygiene as required by Clause G1 "Personal Hygiene".

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Example 2 (Qualitative/Quantitative Code Requirements)

Performance Objective	Performance Requirement
F6.1 The objective of this provision is to safeguard people from injury due to **inadequate** lighting being available during an emergency. **Functional Requirement** F6.2 Buildings shall be provided with **adequate** lighting within all escape routes in an emergency.	F6.3.1 An Illuminance of **1 lux minimum** shall be maintained at floor level throughout buildings for a period equal to 1.5 times the evacuation time. Limit of Application: F6.3.1 shall not apply to spaces infrequently inhabited such as plant rooms, storage areas and service tunnels, and for Housing.

Example 3 (Qualitative/Quantitative Code Requirements)

Performance Objective	Performance Requirement
G8.1 The objective of this provision is to safeguard people from injury due to lack of **adequate** lighting. **Functional Requirement** G8.2 Spaces within buildings used by people, shall be provided with **adequate** artificial light which, when activated in the absence of **sufficient** natural light, will enable safe movement and activity.	G8.3.1 Illuminance at floor level shall be **no less than 20 lux** G8.3.2 Illuminance at activity level shall not be less than that required to carry out intended activity without loss of amenity. Limit of Application: G8.3.1 shall not apply in emergencies, for which Illuminance requirements are given in Clause F6 "Lighting for Emergency."

Examples 1, 2 and 3 are good examples on how performance requirements are well defined in terms of measurable goals.

Example 4 (Qualitative/Quantitative Code Requirements)

Performance Objective	Performance Requirement
E.1.1 The objective of this provision is to: (a) Safeguard people from injury or illness, and other **property from damage**, caused by surface water, and (b) Protect the **outfalls** of drainage systems **Functional Requirement** E1.2 Buildings and sitework shall be constructed in a way that protects people and other property from the adverse effects of surface water.	E1.3.1 Surface water, resulting from a storm having a <u>10%</u> probability of occurring (*exceedance*?) annually and which is collected or concentrated by buildings or sitework, shall be disposed of in a way that avoids the likelihood of damage or nuisance to other property E1.3.2 Surface water, resulting from a storm having a <u>2%</u> probability of occurring annually, shall not enter buildings. Limits of Application: E1.3.2 shall apply only to Housing, Communal Residential and Communal Non-residential buildings.

Example 4 (Qualitative/Quantitative Code Requirements)

Comments:

1. Protecting property from flood damage against a “frequent event” (10% annual probability) may be difficult to achieve for many sites that are too much prone to floods.

2. A Flood Assessment Study with Flood Zoning Maps is required to better understand this issue. Such study should recommend elevations for safe roads and urban areas against floods, evaluate capacity of drainage systems and vulnerability of drainage outfalls.

3. E1.3.2 requirement is unlikely to be achieved by many housing and communal residential buildings. Also, the 2% annual probability correspond to an extreme rain for which life safety and not property damage becomes the performance objective to be achieved by most codes. This performance requirement is recommended for essential facilities only.

Example 5 (Qualitative/Quantitative Code Requirements)

Performance Objective	**Performance Requirement**
B2.1 The objective of this provision is to ensure that a building will **throughout its life** continue to satisfy the other objectives of this code. **Functional Requirement** B2.2. Building materials, components and construction methods shall be **sufficiently** durable to ensure that the building, **without reconstruction or major renovation**, satisfies the other functional requirements of this code throughout the life of the building.	B2.3 From the time a code compliance certificate or a permit to use is issued, building elements shall **with only normal maintenance continue to satisfy** the performances of this code for the lesser or; the specified intended life of the building, if any, or: For the structure, including building elements such as floors and walls which provide structural stability: the life of the building being not less than 50 years.

Example 5 (Qualitative/Quantitative Code Requirements)

Comments:

1. B2.1 and B2.2 are misinterpreting the concept of durability, which pertains to the ability of building materials, components and structures to resist sustained loads during service life, with less than 5% probability of rupture. This probability is measured in the laboratory (materials) or by reliability studies (structures) for a sample of representative specimens.

2. Building components that are non-structural or not part of the structural system that provides stability may have service life of 5 or 10 years. Building components and structures providing stability are required to last for at least for 50 years.

3. B2.1 and B2.2 are also too stringent. Most codes will permit loss of amenity and function under extreme natural hazards of low probability of occurrence. The durability concept is not applicable to transient or temporary loading.

Example 6 (Qualitative/Quantitative Code Requirements)

Performance Objective	Performance Requirement
B1.1 The objective of this provision is to: (a) **Safeguard people from injury** caused by structural failure, (b) Safeguard people from **loss of amenity** caused by structural behavior, and (c) Protect other **property from physical damage**, caused by structural failure **Functional Requirement** B1.2. Building, building elements and sitework shall **withstand the combination of loads** that they are likely to experience during construction or alteration and throughout their lives.	B1.3.1 Building, building elements and sitework shall have a **low probability of rupturing**, becoming unstable, losing equilibrium, or collapsing during construction, or alteration and throughout their lives. B1.3.2 Building, building elements and sitework shall have a **low probability of causing loss of amenity** through undue deformation, vibratory response, degradation, or other physical characteristics **throughout their lives** or during construction, or alteration when the building is in use.

Example 6 (Qualitative/Quantitative Code Requirements)

Comments:

1. B1.3.2 requires building performance to be of low probability of causing loss of amenity throughout building lives. Some building codes will only require full protection against property damage and loss of amenity against the frequent high-probability natural hazards.

2. In many countries affected by severe low-probability natural hazards, buildings are categorized to protect function and operational capacities in **essential facilities** (i.e. hospitals, fire stations, etc.) during such very rare events. Thus, essential facilities will have low probability of losing amenity and experiencing property damage throughout their lives.

3. The concept of safeguarding people from loss of amenity and property protection from physical damage should be defined by measurable performance requirements.

Review of the National Building Code and Compliance Documents
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Performance requirements for life safety

Life safety must be ensure in any building even against the most severe and very rare event with low probability of occurrence.

The Maldivian Building Code should include the following Hazard Zoning Maps that are required by most international building design standards

1. The Basic Wind Design Speed (V_b) with 2% annual probability of exceedance (return period, T = 50 years).
2. The Design Peak Ground Acceleration in Rock (Z value) with 10% probability of exceedance in 50 years (T = 475 years);
3. The Design Rain Precipitation with 2% annual probability of exceedance (T = 50 years)
4. The Design Tide Wave Height with 10% probability of exceedance in 50 years (T = 475 years). Actually designing against Tsunamis is not required in most countries but is being recommended for the Maldives Islands.

These are “Frequent” events that may occur at least one time (rain or wind) or “Rare” events (earthquake and tsunami) that may not occur during buildings’ service life.

Performance requirements for property Damage and loss of amenity protection.

1. The sustained Wind Speed with 10% annual probability of exceedance (return period, T = 10 years) and 99% probability of exceedance during service life (50 years).

2. The Peak Ground Acceleration in Rock with 63% probability of exceedance in 50 years or 2% annual probability of exceedance (T = 50 years).

3. The Rain Precipitation with 20% annual probability of exceedance (T = 5 years) and 100% probability of exceedance during service life (50 years).

These parameters could be used for designing buildings to protect amenities and property. They are considered frequent (earthquake) or very frequent events (wind and rain) that may occur at least one time (earthquake) and several times (rain and wind) during service life of buildings (50 years).

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Performance requirements for property Damage and loss of amenity protection.

Essential Facilities are those required to have operational capabilities during an emergency and after a natural or human made disaster.

SPECIFIED PERFORMANCE REQUIREMENT

Frequency of the Design Event or Hazard		Non-structural Damage		Structural Damage	
		All other Facilities	Essential Facilities	All other Facilities	Essential Facilities
	VERY LARGE (Very Rare)	SEVERE	MODERATE	HIGH	MILD
	LARGE (Rare)	HIGH	MILD	MODERATE	MILD
	MEDIUM (Frequent)	MODERATE	MILD	MILD	MILD
	SMALL (Very Frequent)	MILD	MILD	MILD	MILD

B Stability B1 Structure

OBJECTIVE
B1.1 The objective of this provision is to:
(a) Safeguard people from injury caused by structural failure,
(b) Safeguard people from loss of *amenity* caused by structural behaviour, and
(c) Protect *other property* from physical damage caused by structural failure.

Limits on Application
All *Buildings, building elements* and *sitework* shall be designed in compliance to Compliance Documents B1/B2 issued by MCPI.

Objectives B1.1 (a) and (c) apply to all *buildings, building elements* and *sitework.*

Objective B1.1 (b) applies as follows:

1. For *buildings, building elements* and *sitework* under *permanent loads,* indistinctively from their *building category.*
2. For *buildings* and *building elements* under *temporary loads,* the "***Building Performance Matrix***" specified in **Compliance Document B1/B2** define the level of acceptable damage, as a function of the *building category* and *frequency of design hazard risks*.

B Stability B1 Structure

FUNCTIONAL REQUIREMENT

B1.2 *Buildings, building elements* and *sitework* shall withstand the combination of loads that they are likely to experience during *construction* or *alteration* and throughout their lives.
Design loads and load combinations, shall be computed for all *Buildings, building elements* and *sitework* using "***Design Parameters***" and "***Hazard Risk Zoning Charts***" specified in Compliance Documents B1/B2 for the correspond ***building category*** and ***frequency of design hazard risks.***

PERFORMANCE REQUIREMENTS

B1.3.1 *Buildings, building elements* and *sitework* shall have **5% probability or less** of rupturing, becoming unstable, losing equilibrium, or collapsing during ***construction*** or ***alteration*** and **throughout their lives.**

B1.3.2 *Buildings, building elements* and *sitework* shall have **5% probability or less** of causing loss of ***amenity*** through undue deformation, vibratory response, degradation, or other physical characteristics originated in ***permanent loads*** that are present throughout their ***service life*** or during ***construction*** or ***alteration*** when the *building* is in use.

B Stability B1 Structure

PERFORMANCE REQUIREMENTS

B1.3.3 Account shall be taken of all physical conditions likely to affect the stability of *buildings, building elements* and *sitework,* including:

(a) Self-weight,
(b) Imposed gravity loads arising from use,
(c) Temperature,
(d) Earth pressure,
(e) Water and liquid pressures,
(f) Wind,
(g) *Fire,*
(h) Impact,
(i) Explosion,
(j) Reversing or fluctuating effects,
(k) Differential movement, including soil settlements,
(l) Vegetation,
(m) Adverse effects due to insufficient separation from other *buildings*,
(n) Influence of equipment, services, non-structural elements and contents,
(o) Time dependent effects including creep and shrinkage,
(p) Removal of support

B Stability B1 Structure

PERFORMANCE REQUIREMENTS

(q) Earthquake,
(r) Tsunami,
(s) Water erosion, including sea swell and sea level rise,
(t) Material degradation, including corrosion and wood deterioration,
(u) Second order effects, including dynamic effects,
(v) *Material* imperfections, and
(w) Construction Out-of-plumb.

Performance Objectives and Functional Requirements for building behavior under *temporary loads* shall be accomplished by:

1. Designing *Buildings* and *building elements* to **resist forces imposed by wind, earthquake or rain**, using the applicable *design parameters* specified in Compliance Document B1/B2.

2. Designing *Buildings* and *building elements* **to resist or avoid forces (water pressure and erosion) imposed by Tsunamis, Sea-Swell and Sea-Level-Rise** in compliance with provisions specified in Compliance Document B1/B2.

B Stability COMPLIANCE DOCUMENTS B1 Structure

Building Performance Matrix

Requirements for acceptable structural and non-structural damage in buildings **design** using the **Specified Design Parameters (wind, earthquake and rain)**

Frequency of the Design Event	Non-structural Damage		Structural Damage	
	All other Facilities	Essential Facilities	All other Facilities	Essential Facilities
VERY LARGE (Very Rare)	SEVERE	MODERATE	HIGH	MILD
LARGE (Rare)	HIGH	MILD	MODERATE	MILD
MEDIUM (Ocassional)	MODERATE	MILD	MILD	MILD
SMALL (Frequent)	MILD	MILD	MILD	MILD

Figure 1.6 in B1/B2 Compliance Documents - *Adapted from The International Performance Code for Buildings and Facilities (IPC), United States International Code Council (ICC), 2000.*

B Stability COMPLIANCE DOCUMENTS B1 Structure

Design Provisions for Tsunamis, Sea-Swell and Sea-Level-Rise

The following specifications have to be complied to **avoid** unacceptable damage during **tsunami, sea swell and sea level rise**:

1. Special provisions for **Essential Facilities Building-Category-Group** in **Islands not protected by breakwaters or seawalls**

1.1 Ground Floor shall be open, with no façade and interior partition walls

1.2 Minimum **First Floor Elevation** should be **4 meters** above medium sea level

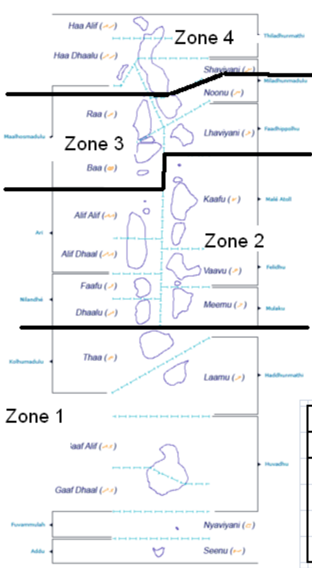
1.3 Facilities shall experience moderate non-structural damage and mild structural damage during the most extreme Tsunami and Cyclone events with 2% probability of exceedance in 50 years (T = 2475 years) and remain operable after such events.

2. Provisions for **Non-Essential Facilities Building-Category-Group**

2.1 Non-essential facilities may experience severe non-structural damage and high structural damage during the most extreme Tsunami and Cyclone events with 2% probability of exceedance in 50 years (T = 2475 years), but shall remain structurally stable after the events.

2.2 Life safety of building occupants and ease of evacuation to designated safe areas or essential facility buildings shall be ensured during Tsunamis and Cyclones. **Fences may be used to break water energy**, protecting buildings from structural collapse

B Stability B1 Structure



COMPLIANCE DOCUMENTS

Wind Design Parameters and Hazard Chart

Table I.4.1 Sustained Wind Speeds for Building Design in Wind Hazard Zones

SUSTAINED WIND SPEEDS				
ZONE	T = 50 years, Vb ** for life safety design using BS 6399-2		T = 25 years, for Property Loss Protection*	
	KM/H	m/s	KM/H	m/s
4	140	39	80	22
3	120	33	70	19
2	100	28	60	17
1	80	22	50	14

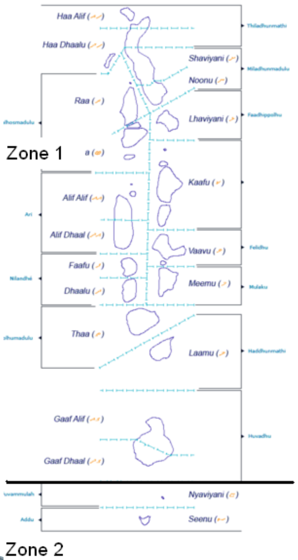
*Best estimate – not computed

** Adapted from values computed in UNDP – RMSI (2006) study for gusty winds with T = 500years

WIND HAZARD RISK	
HAZARD ZONE	RISK LEVEL
1	Very Low
2	Low
3	Moderate
4	High

B Stability

B1 Structure



COMPLIANCE DOCUMENTS

Earthquake Design Parameters and Hazard Chart

Table I.4.2 Zone Factors (Z) for Building Design in Earthquake Hazard Zones

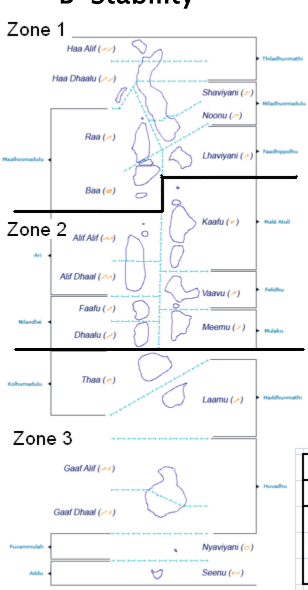
Zone Factors (Z = PGA/g); *g = 9.81 m/s^2 (gravity acceleration)*		
ZONE	**T = 475 years, for life safety design using IS 1893 (Part I)****	**T = 50 years, for Property Loss Protection***
1	0.10	0.02
2	0.16	0.03

*Best estimate – not computed
** Revised from values computed in UNDP – RMSI (2006) study for T = 475 years

EARTHQUAKE HAZARD RISK	
HAZARD ZONE	**RISK LEVEL**
1	Low
2	Moderate

B Stability

B1 Structure



COMPLIANCE DOCUMENTS

Rain Design Parameters and Hazard Chart

Table I.4.3 Rain Precipitation Values for Building Design in Rain Hazard Zones

Rain Hazard Zone	**Maximum Rain Precipitation (mm)**		
	T = 10 years, for Section E1.3.1 in MBC*	**T = 50 years, for Section E1.3.2 in MBC Property Loss Protection****	**T = 500 years, for Chapter B in MBC Life Safety****
1	130	140	180
2	180	190	240
3	210	220	280

*Best estimate – not computed by the UNDP – RMSI (2006) study
** Computed by the UNDP – RMSI (2006) study

RAIN HAZARD RISK	
HAZARD ZONE	**RISK LEVEL**
1	Moderate
2	High
3	Very High

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B Stability B1 Structure

PERFORMANCE REQUIREMENTS

B1.3.8 Building foundation shall be constructed at a depth below ground-surface-level not smaller than:

1) 0.5 meters
2) The depth that ensures that the expected environmental erosion, through *service life* of building, of soil above the foundation level, do not reduce by more than 5% the soil allowable-bearing-capacity below the foundation level.

Agree with Dr. Kuuyuor's proposal to add B1.3.9 and B.3.10 with reformulation:

B1.3.9 *Buildings* and *building elements* made of steel shall be protected against deterioration from corrosion activity.
Building elements shall be provided with a thicker section than the required by their design for permanent loads, to account for material section lost due to corrosion during building *service life.*
Steel *materials* in *Building* shall be protected with an anticorrosive coating and provided with periodical maintenance to reduce deterioration effects from corrosion on *building* stability and durability.

B1.3.10 A geotechnical site investigation shall be performed for the foundation design of *essential facilities* and all other buildings with two or more stories.

B Stability B2 Durability

OBJECTIVE

B2.1 The objective of this provision is to ensure that a *building* will throughout its life continue to satisfy the other objectives of this code.

FUNCTIONAL REQUIREMENT

B2.2 *Materials* in *buildings* and *building elements* shall be sufficiently durable, under the action of *permanent loads*, to ensure that the *building,* without reconstruction or major renovation, satisfies the other functional requirements of this code throughout the *service life* of the *building.*

PERFORMANCE REQUIREMENTS

B2.3.1 From the time a code compliance certificate or a permit to use is issued, *building elements,* that are **part of the structural system** providing stability to the building, shall **with only normal maintenance** continue to satisfy the performance requirements of this code, under the action of permanent loads, throughout the ***service life*** of the building, which shall not be less than:

(a) 75 years, for building within the essential facilities building category group defined in Compliance Document B1/B2, or
(b) 50 years, for all other buildings

Recommended Tsunami Design Specifications for Maldives Islands

1. Special provisions for the Essential Facilities Building Category Group

1.1. Ground Floor shall be open, with no façade and interior partition walls

1.2. First Floor Elevation should be not less than 4 m above MSL

2. All other Facilities will be permitted to experience severe damage for the Tsunami design event

2.1 Life safety of building occupants in all facilities must be ensured

2.2. Early warning and ease evacuation of building occupants to essential facilities designated as "safe places" shall be provided

Summary Code and Compliance Documents Review and Main Recommendations for Building Code Improvement

1. Insert references in Building Code of applicable Compliance Documents in each Chapter
2. Define Performance Requirements with quantitative format, setting the minimum standard of safety and building performance in measurable terms, facilitating future code enforcement and homologation with building codes from other countries.
3. Fire safety has to be accounted thoroughly, as appears to be the most life safety and property damage hazard in Maldives

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Summary Code and Compliance Documents Review and Main Recommendations for Building Code Improvement

4. Performance Requirements for Durability against Sustained (Permanent) Loads and for Stability against Sustained and Transient (Temporary) Loads should be clearly distinguished and defined in measurable terms.

5. Parameters for Building Design against Natural Hazards (transient loads) shall be provided in the international standardized format, using Zoning Maps, to allow use of the specified British Standards and to facilitate homologation with alternative solutions from building design codes elsewhere in the world.

E Moisture – E1 Surface Water

FUNCTIONAL REQUIREMENT

E1.2 *Buildings* and *sitework* shall be constructed in a way that protects people and *other property* from the adverse effects of *surface water.*

PERFORMANCE REQUIREMENTS

E1.3.1 *Surface water*, resulting from a storm having a 10% probability of occurring annually and which is collected or concentrated by *buildings* or *sitework*, shall be disposed of in a way that avoids the likelihood of damage or nuisance to *other property*.

E1.3.2 *Surface water*, resulting from a storm having a 2% probability of occurring annually, shall not enter *buildings.*

Change Limits on Application

Performance E1.3.2 shall apply only to *Essential Facility Buildings*

E Moisture – E1 Surface Water

COMPLIANCE DOCUMENTS

Acceptable Solution E1 / AS1 – Modify the following:

E1 /AS1 is limited to buildings and sitework having a catchment area of no more than 1,000 square meters. Suspended floors and slabs on ground shall be at an elevation that satisfies the following criteria:

a) For sites located at an elevation equal or higher than 1.0 m above medium seal level and free from a history of flooding (Flood Hazard Risk Maps):

Design Criteria	Minimum Elevation (mm)	
	Essential Facilities	All other Facilities
Building footprint above: 1. The adjacent road crown on at least one cross-section through the building (see Figure 1), or 2. The lowest point on site boundary (Figure 2), where site is below the adjacent road	300	150

E Moisture E1 Surface Water

COMPLIANCE DOCUMENTS (Continuation)

b) For sites located at an elevation lower than 1.0 meters above medium seal level or adjacent to sea, a watercourse or a secondary flow path, the most stringent criteria govern:

Design Criteria	Minimum Elevation (mm)	
	Essential Facilities	All other Facilities
1. Minimum Height above medium sea level elevation	1,300	1,150
2. The height recommended by a site-specific Flood Hazard Map	N/A	N/A

E Moisture — E2 External Moisture

FUNCTIONAL REQUIREMENT

E2.2 *Buildings* shall be constructed watertight, to avoid water penetration into building and moisture accumulation from the outside.

PERFORMANCE REQUIREMENTS

Change E.2.3.4 as follows

E2.3.4 *Concealed spaces* and cavities in *buildings* shall be water-tightened and constructed in a way which prevents external moisture being transferred and causing condensation and the degradation of *building elements.*

Add the following provision:

E.2.3.6 Roofs shall be provided with a drainage system composed of drains, gutters and downspouts to avoid water falling on walkways, parking and roads. Downspouts shall be connected to surface water sumps, avoiding rain water discharge on street sidewalks or walkways.

G Services & Facilities — G9 Electricity

OBJECTIVE - Change G9.1 as follows:

G9.1 The objective of this provision is to ensure that:
(a) In *buildings* supplied with electricity, the *electrical installation* has safeguards against outbreak of *fire* and personal injury, and
(b) People with disabilities are able to carry out normal activities and processes within building.

PERFORMANCE REQUIREMENTS

Change G9.3.2 as follows:

G9.3.2 An *electrical installation* supplying energy to an *essential facility* shall:
(a) Maintain the energy supply at all times under normal operating conditions,
(b) Be capable of being isolated from the supply system, independently of the remainder of the installation, and
(c) Have an alternate energy supply source, such as an emergency power generator, that is redundant and independent from the electrical installation.

G Services & Facilities G11 Gas as an energy source

FUNCTIONAL REQUIREMENT

G11.2 In *buildings* where gas is used as an energy source, the supply system shall be safe and *adequate* for its *intended use.*

PERFORMANCE REQUIREMENTS

G11.3.1 LPG cylinders used as gas supply system, shall be used, stored, transported and maintained following manufacturer's specifications. Where pipe supply systems are used, they shall be constructed to maintain a safe pressure range appropriate to the appliances and type of gas used.

G11.3.2 The LPG cylinders shall:
(a) Always be kept cool and away from flames, sparks and heat,
(b) Never be filled with automotive LPG (Autogas),
(c) Be stored in a well ventilated and protected area,
(d) Be carried and stored upright at all times, and
(e) Have pressure relief valves facing away from combustible materials.

G11.3.4 Valves in LPG cylinders shall:
(a) Not be open or close using an undue force,
(b) Be shut off before disconnecting the cylinder from the appliance, and
(c) Turn off firmly when cylinder is not in use.

G Services & Facilities G11 Gas as an energy source

PERFORMANCE REQUIREMENTS

G11.3.5 Where gas is supplied from a pipe supply system connected to LPG cylinders or a different external source of gas, the supply system within *buildings* shall be constructed to avoid the likelihood of:
(a) Contamination of the pipe supply system within the *building,*
(b) Adverse effects on the pressure in the pipe supply system and external source, and
(c) The pipe supply system acting as an earthing conductor.

G11.3.6 The LPG cylinders shall be maintained and inspected for safety and shall be:
(a) Required to be re-tested and stamped every 10 years.
(b) Inspected for gas leakage by spraying soapy water on any suspect connection or hose and watch for bubbles.
(c) Kept free of dents and corrosion.

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G Services & Facilities G12 Gas as an energy source

PERFORMANCE REQUIREMENTS

G12.3.4 Where hot water is provided to *sanitary fixtures* and *sanitary appliances,* used for personal hygiene, it shall be delivered at a temperature which avoids the likelihood of scalding and shall not be higher than:
(a) 45°C for sanitary fixtures in facilities designed for children
(b) 55°C in all other facilities

Change G12.3.5 (d) as follows:
Allows access to mechanical components for maintenance personal and equipment, with the space required for *adequate* operations, and

Change G12.3.6 (b) as follows:
(b) Limit water temperature below 95°C to avoid the likelihood of flash steam production in the event of rupture.

Change G12.3.7 as follows:
G12.3.7 Storage water heaters shall be capable of being controlled to produce, at the outlet of the storage water heater, a water temperature of not less than 60°C to prevent the growth of legionalla bacteria.

Road Map to Enhance the MNBC-2008

Objectives

(a) Increase Safety, Health and Wellbeing of people
(b) Institutionalize a sustainable process for "Building Code Use, Enhancement and Enforcement" in the Republic of Maldives
(c) Strengthen the preventive capacity in the private and public sectors to face emergency situations
(d) Strengthen local knowledge on techniques to mitigate losses in buildings due to natural and human-made hazards, vulnerabilities and risks
(e) Improve safety and protect operational capacities of Essential Facilities to face an emergency situation
(f) Improve and renew the existing urban cadastre in low-risk conditions
(g) Plan for the Building Construction Industry to contribute to a sustainable environment with low environmental impact and risk against natural and human-made hazards
(h) Risk reduction through concrete and measurable actions in the Building Construction Industry against life and property losses
(i) Improve performance of new buildings against natural and human-made hazard risks
(j) Develop awareness in local communities on risk prevention and preparedness to face hazards, vulnerabilities and risks in buildings

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Road Map to Enhance the MNBC-2008

Goals

(a) To form 21 Building Safety Units (BSUs) at local communities (atoll governments and Male Municipality) to institutionalize a sustainable process, and execute the Road Map
(b) To train Building Officials from BSUs, in local communities, on the prevention and reduction of natural and human-made hazard risks through building inspection and code enforcement
(c) To train specialized groups within the Building Code stakeholders, at the national level, on the prevention and reduction of natural and human-made hazard risks through building inspection and code enforcement within limits of their duties and responsibilities
(d) To train specialized groups, at the national and regional level, on use and development of planning tools for assessment and mitigation of natural and human-made hazard risks in buildings
(e) To prepare master plans for the Country, Atolls and Islands for risk reduction in the building construction industry
(f) To study in detail the safety and expected performance of essential facilities and to design the necessary actions to mitigate damage: strengthening projects, change of use, construction projects for new facilities, etc.
(g) To identify buildings at risk, and promote projects for urban and rural renovation in high risk zones

- **Review of the MNBC-2008 and its Compliance Documents**
- **April 2010, MHTE - Republic of Maldives**

Road Map to Enhance the MNBC-2008

Goals

(h) To support MHTE on updating, implementing and enforcing the "Building Code"
(i) To devise regulatory, control and safety actions for critical infrastructure other than buildings, such as airports, ports, seawalls, industrial installations, gas stations, energy power plants, etc
(j) To support monitoring and study of natural hazards
(k) To update knowledge in professionals on natural and man-made hazard risks and the techniques to mitigate loss of lives and economic losses
(l) To incorporate special provisions for risk prevention and reduction in essential facility projects at planning and design phases
(m) To educate the people of Maldives in risk prevention regulations for self protection during and after emergency situations
(n) To train local communities on the identification of their natural and human-made hazard risks and in the preparation of contingency plans at the community level
(o) To support national, regional and local construction projects addressing risk reduction and mitigation
(p) To involve the private sectors in the preparation of contingency plans for their sectors (tourism, fishery, agriculture, etc) to reduce loss of lives and economic losses during natural and human-made hazard risks

- **Review of the MNBC-2008 and its Compliance Documents**
- **April 2010, MHTE - Republic of Maldives**

Road Map to Enhance the MNBC-2008

Initiatives (Approximate Cost/Time Estimates: 1,4 million USD/2 years)

Five Initiatives are recommended for the Road Map. Initiatives are proposed to ensure that the Road Map Objectives are accomplished

1. Institutionalization and Capacity Building Process in the government for risk reduction, prevention and mitigation within Building Code framework (***Building Code Enforcement)***
2. Planning, Regulations and Actions in the public sector for Building Code enhancement and sustainable building construction
3. Risk Assessment Studies and Actions to Mitigate Damage in the Public Infrastructure and to Increase Public Safety
4. Risk Reduction Actions in the Building Construction Industry
5. Public Awareness and Local Community Actions for risk reduction, prevention and mitigation in buildings

*The Road Map was designed as an "**Action Plan**" with "**Objectives**", "**Goals**", "**Initiatives**" and "**Projects**" that are grouped within each Initiative.*
*The "**Action Plan**" design follows the methodology used by **GeoHazards International** in the **RADIUS 1999** project.*

Road Map to Enforce the MNBC-2008 (Initiative No. 1)

Institutionalization and Capacity Building Process in the government for risk reduction, prevention and mitigation within Building Code framework

1. Revision and issuance of the Maldives National Building Code 2010 with amendments after UNDP consultant work and latest input from stakeholders
   a. Integration of New Stakeholders in MNBC 2010 Code (Introduction Section)
   b. Inclusion of New Clauses in MNBC for Code
      i. A3: Administration
      ii. A4: General Building Heights and Areas
      iii. A5: Existing Buildings
   c. Addition of New Compliances Documents incorporated by Reference (Name or Title of Regulatory Document) in A3 Clause for:
      i. Mosques Infrastructure
      ii. Health Facilities Infrastructure
      iii. Education Facilities Infrastructure
      iv. Airports and Ports Infrastructure
   d. Input from Fire Engineer specialized in Fire Code Provisions to improve Clauses C1, C2, C3 and C4

2. Revision and issuance of the Maldives Building Act 2010

Road Map to Enforce the MNBC-2008 (Initiative No. 1)

3. Constitution of BSUs in 20 Atoll Administrative Divisions (Regional Governments) and Male Municipality.
4. Training of Building Officials in 21 BSUs on Building Code use and enforcement
5. Development and publication of documents to train Building Officials from BSUs on Use and Enforcement of the MNBC 2010 and its Compliance Documents.
6. Development and publication of guidelines containing typical details and checklists for safe construction and code compliance in 1-story and 2-stories housing for:
   a. Code Enforcement by BSUs in 1-story and 2-stories housing projects
   b. Community Awareness on how to build safe housing projects
7. MNBC-2010 Trainee Programs for government officials (architects, engineers, technicians) in MHTE on building code planning, design, construction supervision and inspections at construction site and hazardous existing buildings to prevent and reduce natural and human-made hazard risks (Building Inspectors Trainee Program).
8. Trainee Programs to government officials from stakeholders (other than MHTE and BSUs) to enforce compliance of MNBC-2010 and its Compliance Documents on specialized issues.

***Note**: This initiative has been addressed by M. Marafatto (March 2010) with a different format, with some differences in activities, but similar scope.*

- Review of the MNBC-2008 and its Compliance Documents
- April 2010, MHTE - Republic of Maldives