CE – 842, Credits: 3 + 0, Semester: Spring 2022

Performance-based Seismic Design of Structures

Department of Structural Engineering

National University of Sciences and Technology (NUST)

Course Introduction

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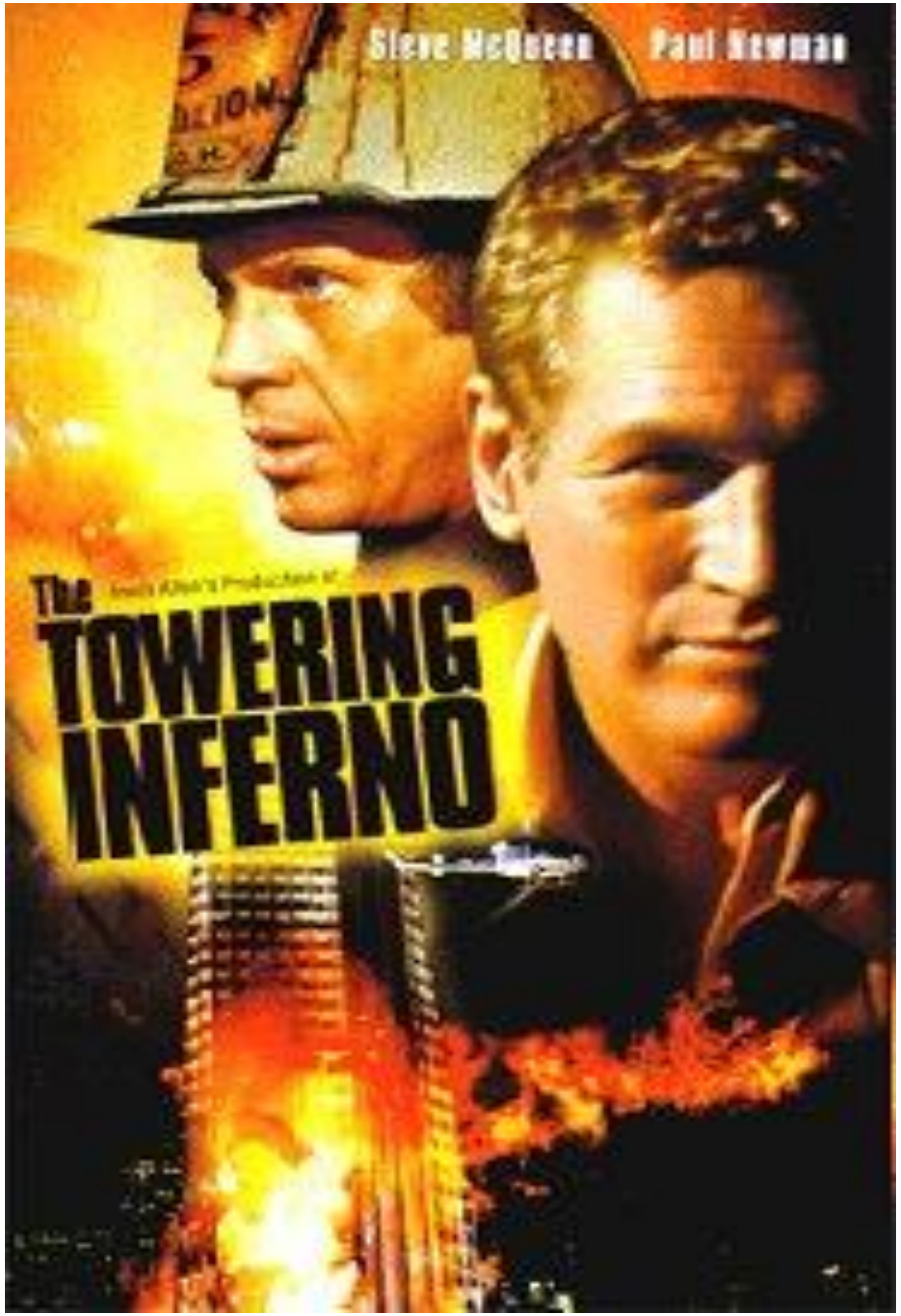
Why This Course?

- **Aspect 1:** Traditional Building Codes
- **Aspect 2:** Rapid Urbanization
- **Aspect 3:** Seismic Hazard

How long do we have before the building will collapse in this fire?

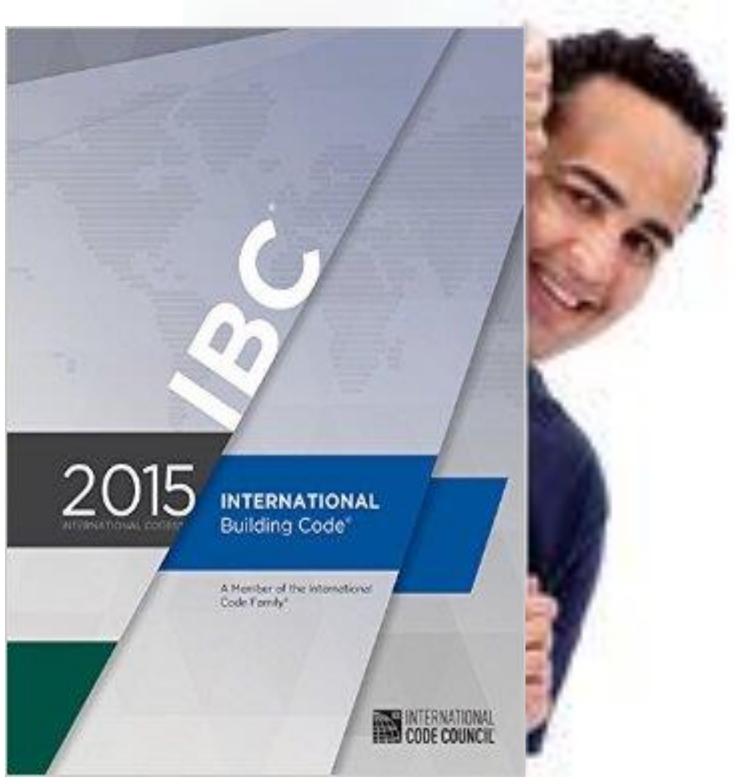
- Fire Chief from the structural engineer/(Architect)

The Towering Inferno (1974)



Why this course?

- **Public:**
  - Will the building be safe?
- **Owner:**
  - Will the building collapse/ will it be damaged ?
  - Can I use the building after a given earthquake?
  - How much will repair cost?
  - How long will it take to repair?
  - Can I make building that will not be damaged and will not collapse?
- **Public Officials:**
  - Who is responsible if loss of life occurs?
- **Structural Engineer:**
  - *Not sure, but I did follow the "Code"*

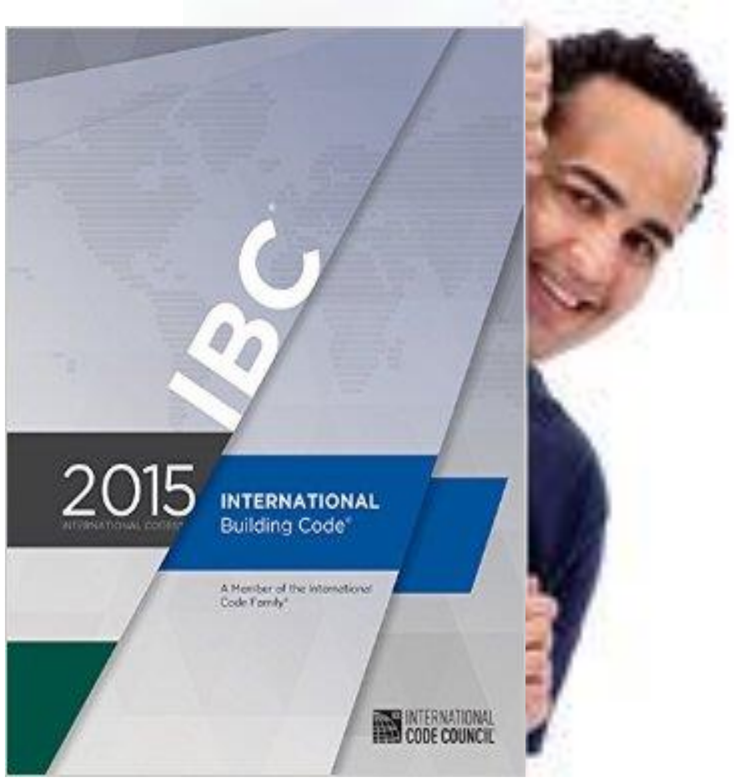


Prescriptive Codes – A Shelter

Structural Engineer's Dilemma

- Can not answer most of these questions explicitly.
- There is no warranty for the structure.
- There are too many unknowns.
- Public understanding and engineers understanding of safety is different.
- Has to hide behind the design codes.

As long as engineers follow the code, they can be sheltered by its provisions.



Prescriptive Codes – A Shelter

Building Industry relies on Codes and Standards

- Specify requirements
- Give acceptable solutions
- Prescribe (detailed) procedures, rules, limits
- Mostly based on experience and not always rational

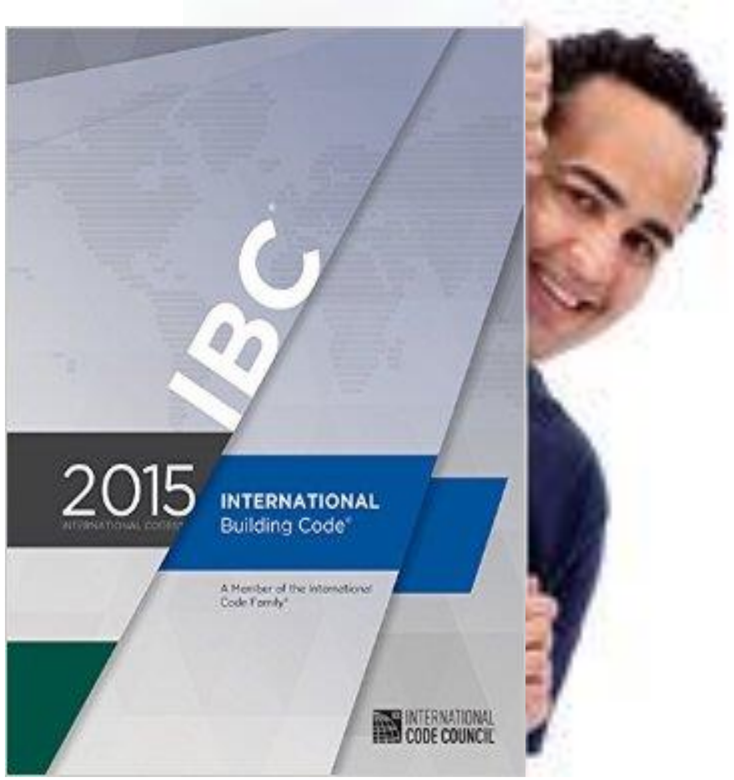
- **Spirit of the code to provide public safety and convenience.**
- **Compliance to letter of the code is indented to meet the spirit.**

Prescriptive Codes – A Shelter

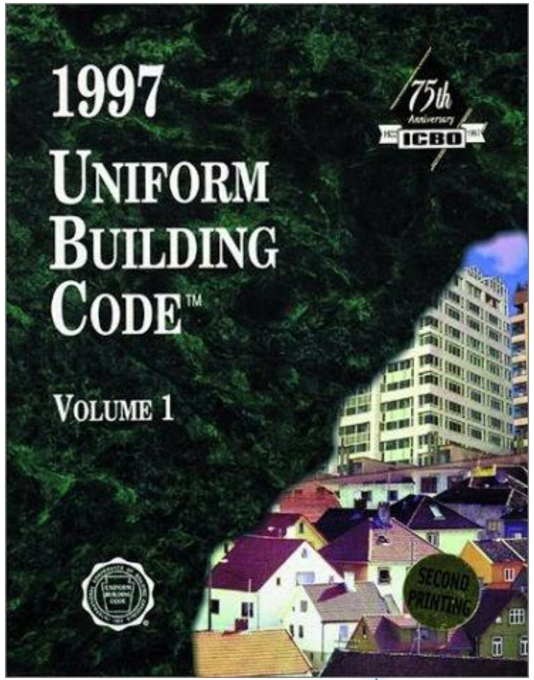
- The building codes implicitly ensures that the performance of structure will be acceptable if its rules are followed.
- *The performance may not be acceptable in certain cases.*

So, we end up in changing the rules every three years,

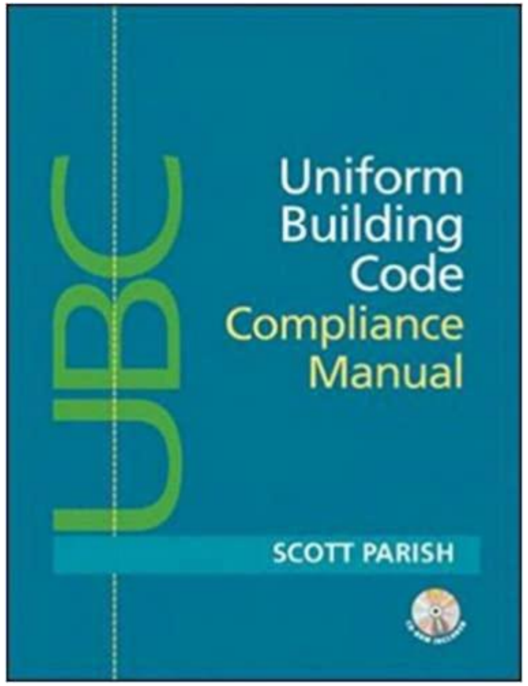
Or invent new rules.

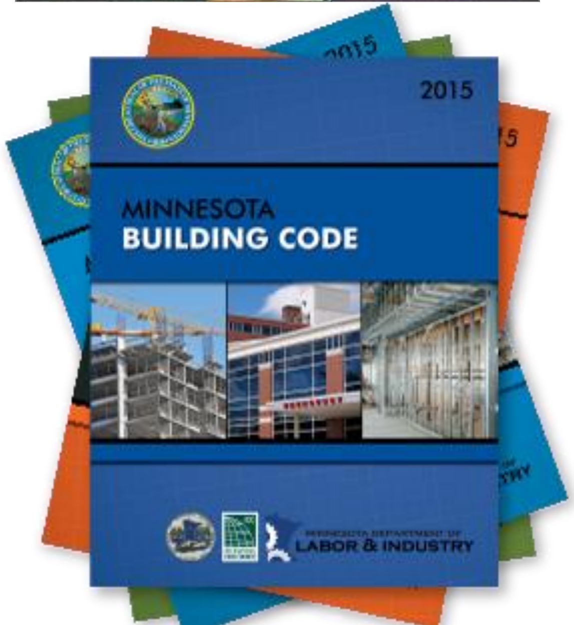


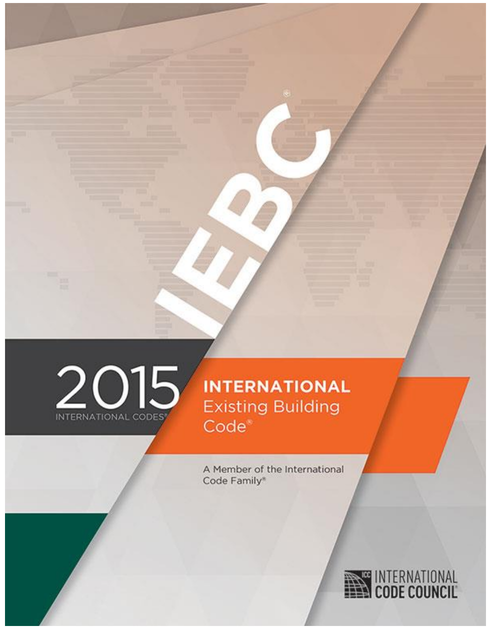
Prescriptive Codes – A Shelter


1997
UNIFORM BUILDING CODE™
VOLUME 1
75th Anniversary
ICBO
SECOND PRINTING

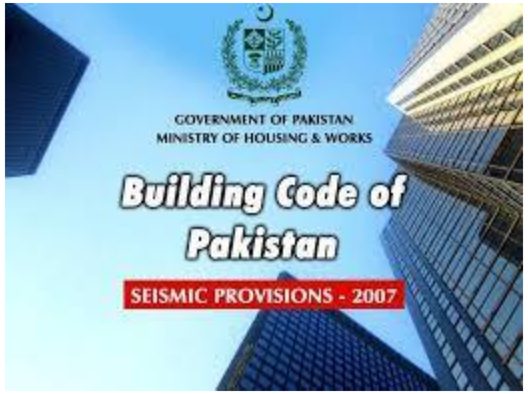

National Construction Code Series
VOLUME ONE
Building Code of Australia 2011
Class 2 to Class 9 Buildings
ABCB


UBC
Uniform Building Code Compliance Manual
SCOTT PARISH


2015
MINNESOTA
BUILDING CODE
LABOR & INDUSTRY


IEBC
2015
INTERNATIONAL CODES
INTERNATIONAL
Existing Building
Code
A Member of the International Code Family
INTERNATIONAL CODE COUNCIL


INTERNATIONAL BUILDING CODE
2018
IBC
INTERNATIONAL BUILDING CODE
BBI FAST - TABS
IBC
2018
Based on INTERNATIONAL BUILDING CODE
Builder's Book Inc.


GOVERNMENT OF PAKISTAN
MINISTRY OF HOUSING & WORKS
Building Code of Pakistan
SEISMIC PROVISIONS - 2007

Shortcomings of Code Based Design for Tall Buildings

- Traditional codes govern design of general, normal, low-rise buildings
- Not specifically developed for tall buildings > 50 m tall
- Prescriptive in nature, no explicit check on outcome
- Permit a limited number of structural systems
- Do not include framing systems appropriate for high-rise
- Based on elastic methods of analysis
- Enforce uniform detailing rules on all members
- Enforce unreasonable demand distribution rules
- Do not take advantage of recent computing tools

Are All Buildings Codes Correct ?

- If they differ, can all of them be correct?
- Did we inform the structures to follow which code when earthquake or hurricane strikes?
- Codes change every 3 or 5 years, should we upgrade our structures every 3 or 5 years to conform?
- Codes intend for “Life Safety”, not damage limits or cost implications.

The First Code - Hammurabi's (1792 BC to 1750 BC)

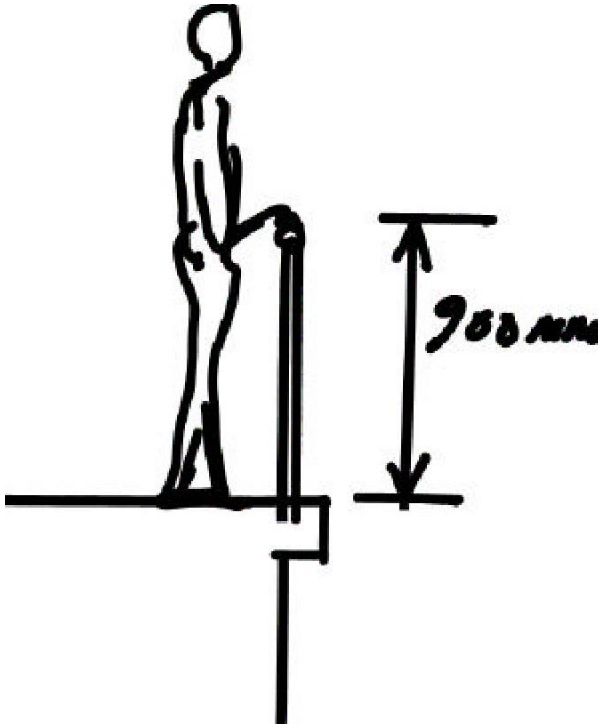
Clause 229: If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then that builder shall be put to death.

Implicit Requirements — not construct it properly,

Explicit Collapse Performance — built falls in and kills its owner,

Consequence of Non-performance — shall be put to death.

Public Safety and the Codes



“In case you build a new house, you must also ***make a parapet*** *for your roof, that you may not place bloodguilt upon your house because someone* ***falling might fall from it****”*

Prescriptive

Modern Codes, c2000

Ref: Teh Kem, Associate Prof. NUS

Performance Oriented

Law of Moses (1300 BC)

The Bible, Book of Deuteronomy, Chapter 22, Verse 8

How modern codes intent to ensure "Safety"

- Define appropriate/estimated hazard or load levels
- Prescribe limits on structural systems, members, materials
- Define procedures for analysis and design
- Provide rules for detailing
- Provide specifications for construction and monitoring

- **Hope that all of this will lead to reduced vulnerability and safer structures …**

The Modern Codes – With “intent” to make buildings safe for public

7.2.3 — Inside diameter of bend in welded wire reinforcement for stirrups and ties shall not be less than $4d_b$ for deformed wire larger than MD40 and $2d_b$ for all other wires. Bends with inside diameter of less than $8d_b$ shall not be less than $4d_b$ from nearest welded intersection.

(ACI 318 – 11)

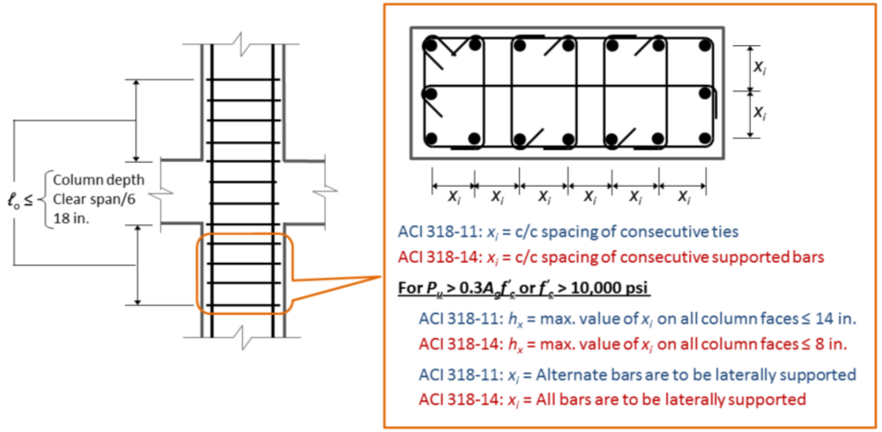
a) A beam shall be deemed to be a deep beam when the ratio of effective span to overall depth, $\frac{l}{D}$ is less than:

1) 2.0 for a simply supported beam; and
2) 2.5 for a continuous beam.

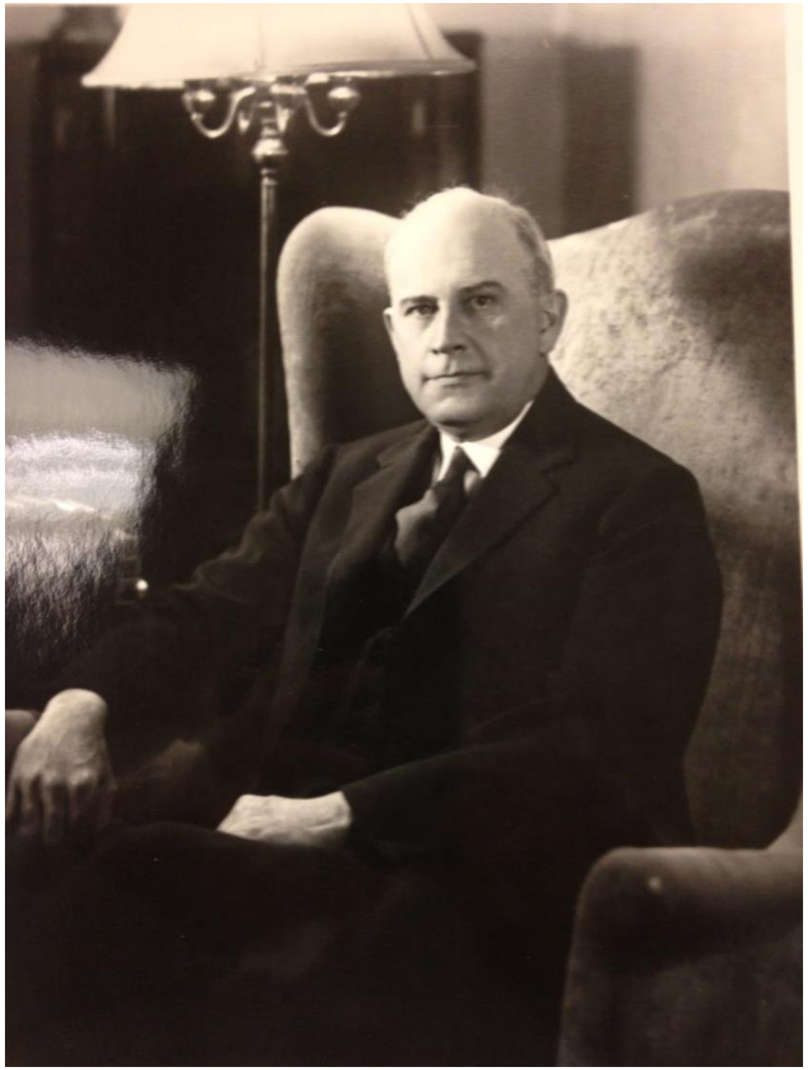
b) A deep beam complying with the requirements of 29.2 and 29.3 shall be deemed to satisfy the provisions for shear.

(IS 456-2000)

Extremely Detailed prescriptions and equations using seemingly arbitrary, rounded limits with implicit meaning



On the Standardization …



As the size and complexity of projects increased, … it became desirable and even necessary to … set up a series of routine procedures for analysis and design.

With these standardized formulas and specifications and methods it became possible to use a greater number of men and men with less training to produce engineering works …

Standardization … as a check on fools and rascals or set up as an intellectual assembly line, has served well in the engineering world"

– Hardy Cross

Engineers and Ivory Towers, 1952

Taken from CEE Spring Distinguished lecture by Prof. Jack Moehle - PEER

Structural Engineers are “trained” to follow the procedures and equations and rules and be conformists

Whereas Architects are encouraged to dream and be “defiant”

Determine the wall thickness and reinforcement
(6x2x3m)

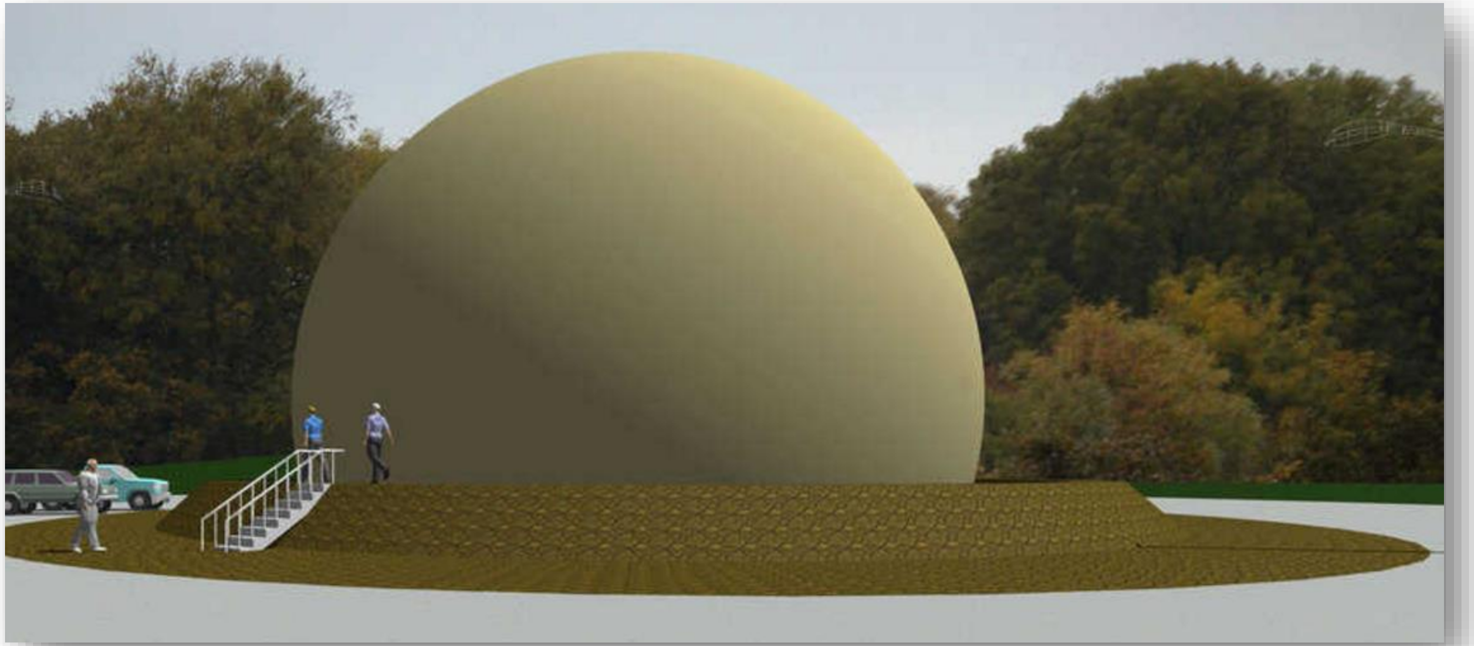
Most structural engineer should be able to do

Design the most
cost effective water tank to hold 36 m^3 of water

Most Structural Engineers would not know what to do

(Will need a "Structural Designer")

Design the most
cost effective, beautiful, and amazing water tank to hold 36 m^3 of water



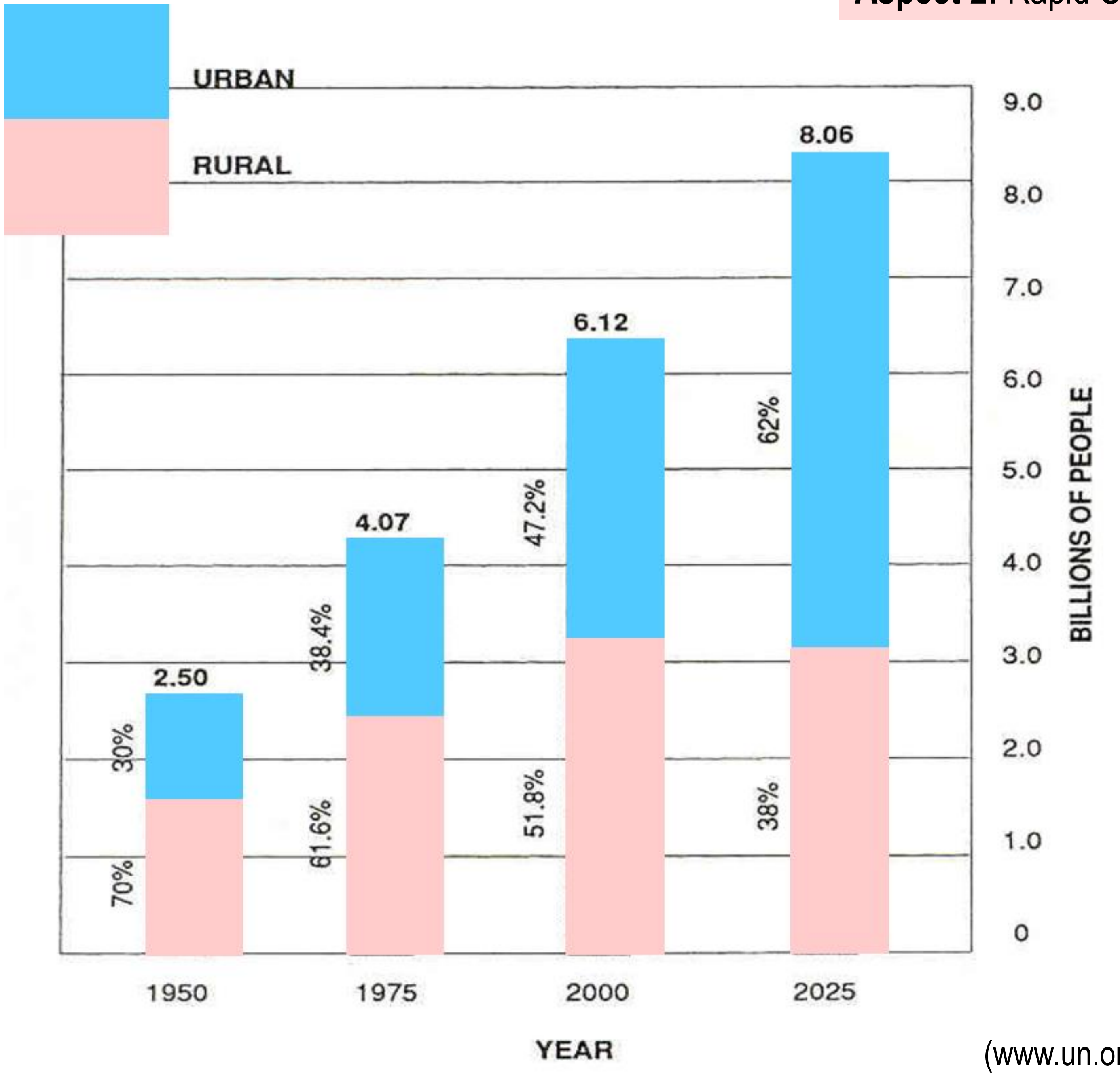
Performance + Cost + Aesthetes → Will need "Structural Artist"

Unsuitability of Traditional Design Codes

- Implicit Performance Objective
  - Resist minor earthquake without damage, which is anticipated to occur several times during the life of a building, without damage to structural and non-structural components.
  - Resist the design level of earthquake with damage without causing loss of life.
  - Resist strongest earthquake with substantial damage but a very low probability of collapse.
- Explicit verification not specified or required.

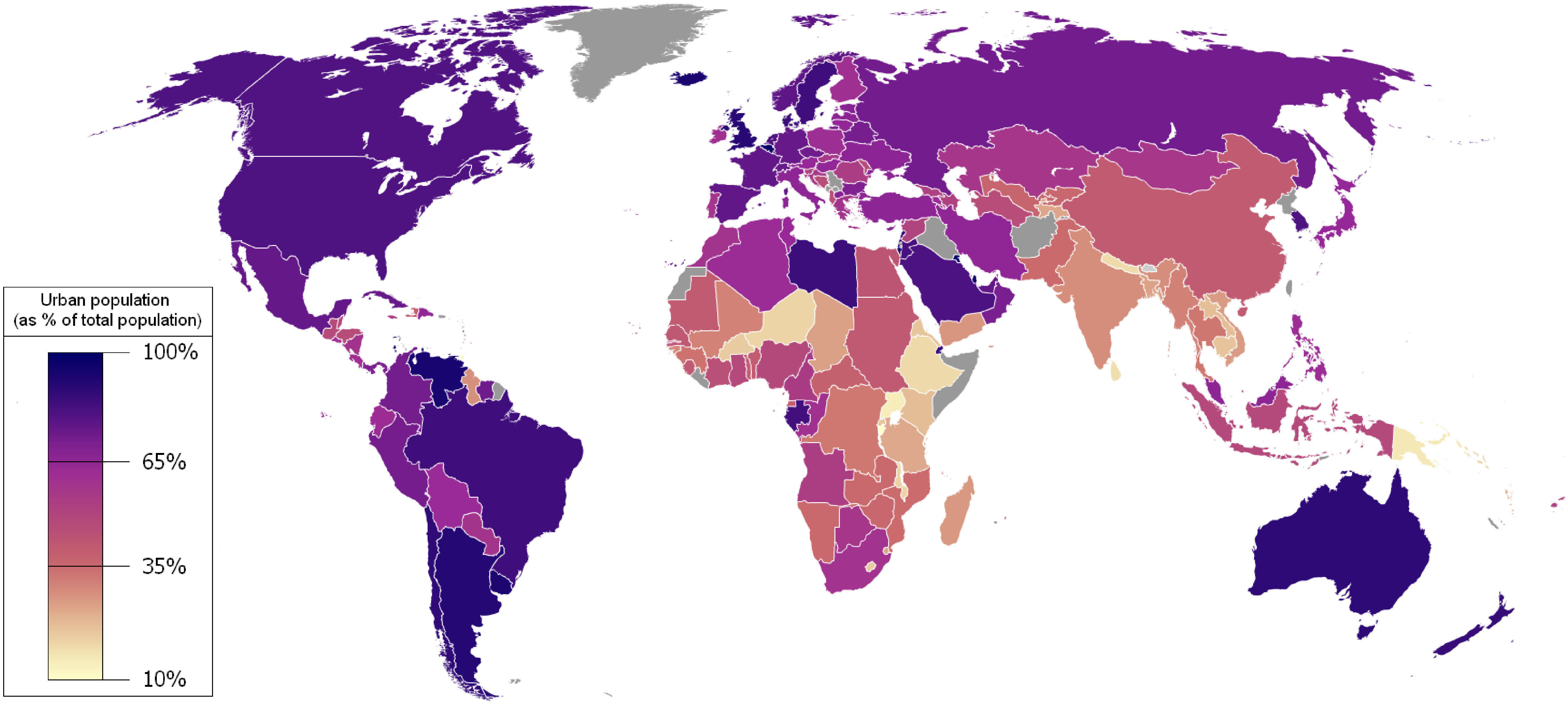
World's Population

Urban-to-Rural Ratio



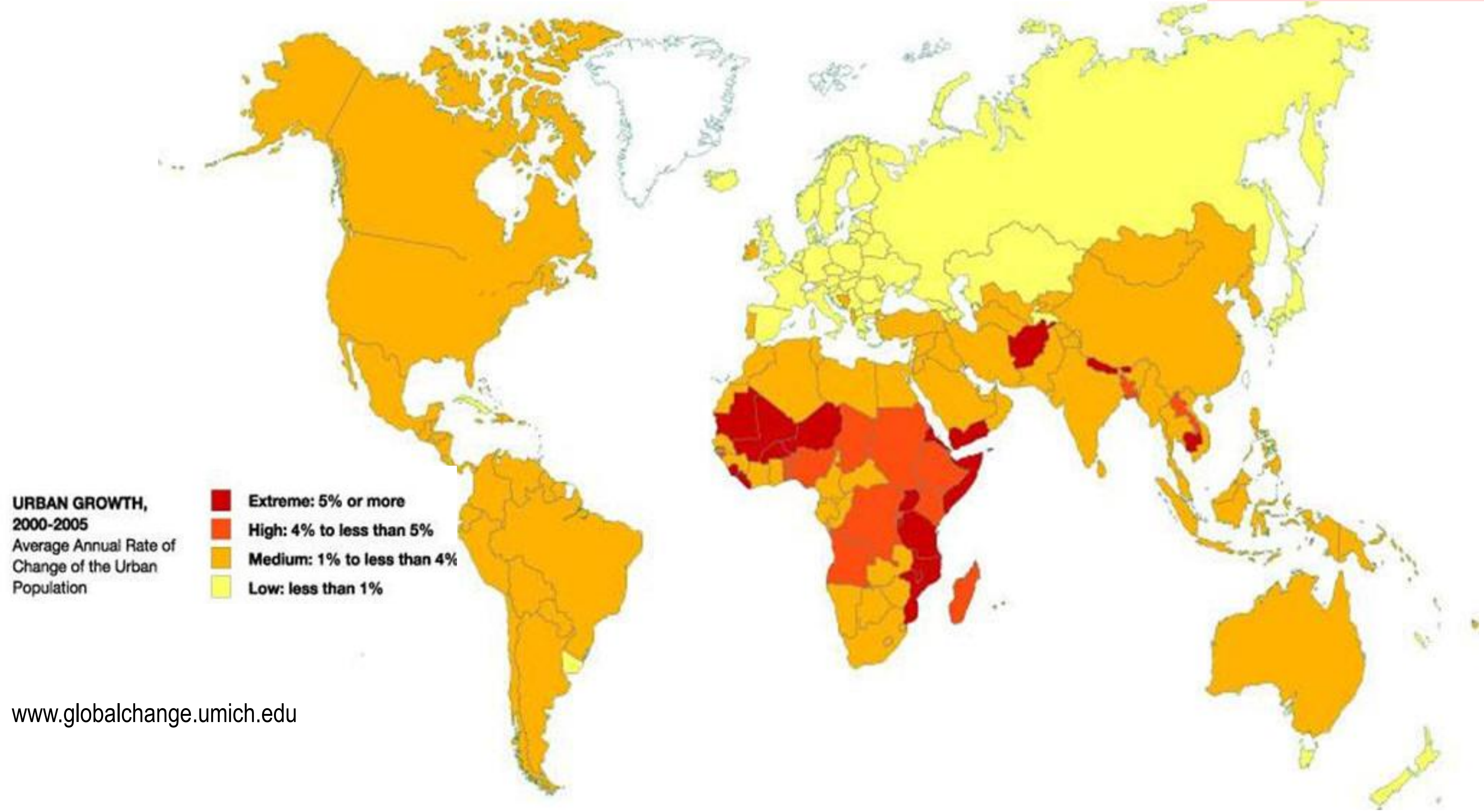
(www.un.org)

Rapid Urbanization



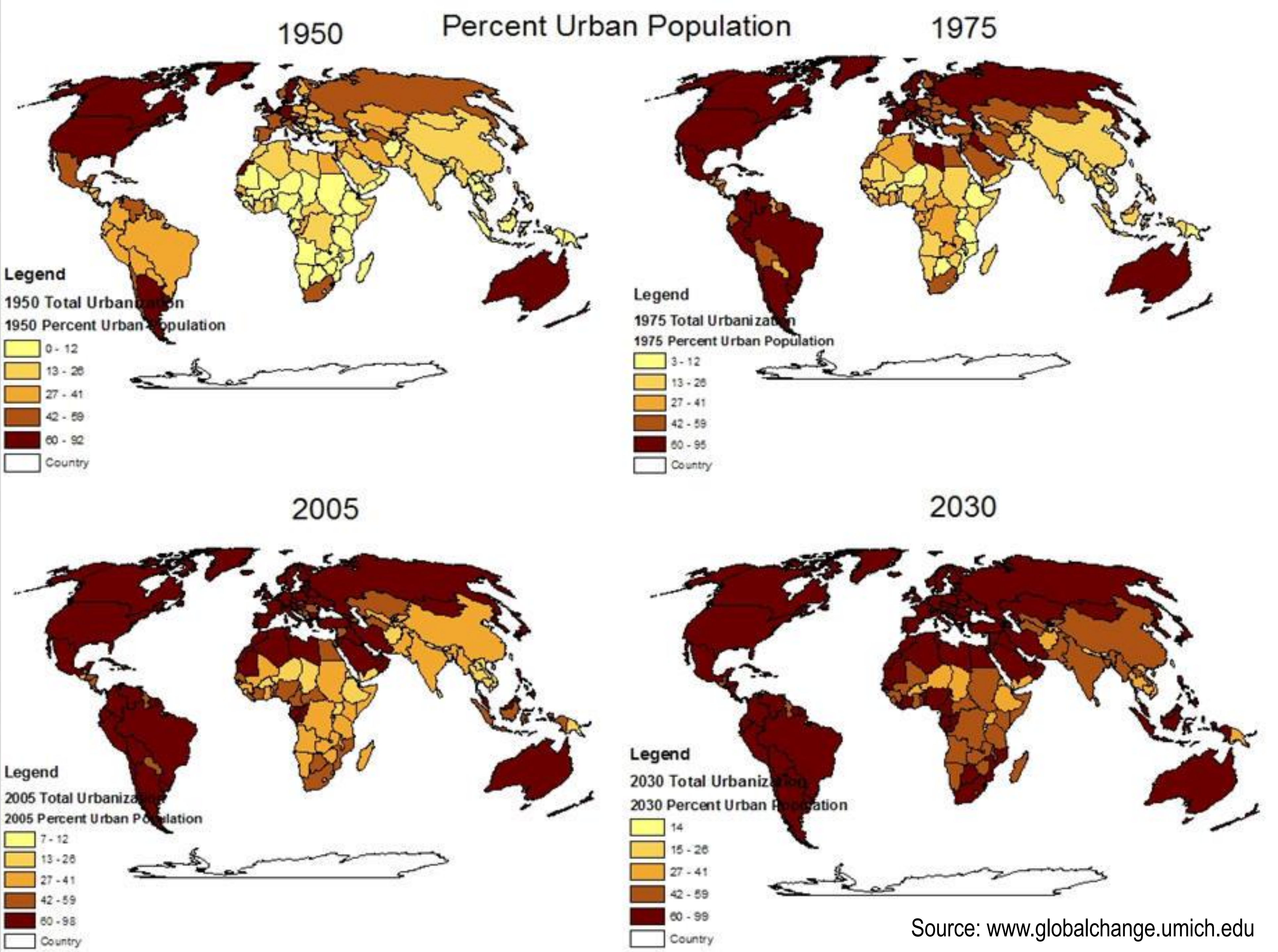
Source: UN Human Development Report 2007/2008

Aspect 2: Rapid Urbanization



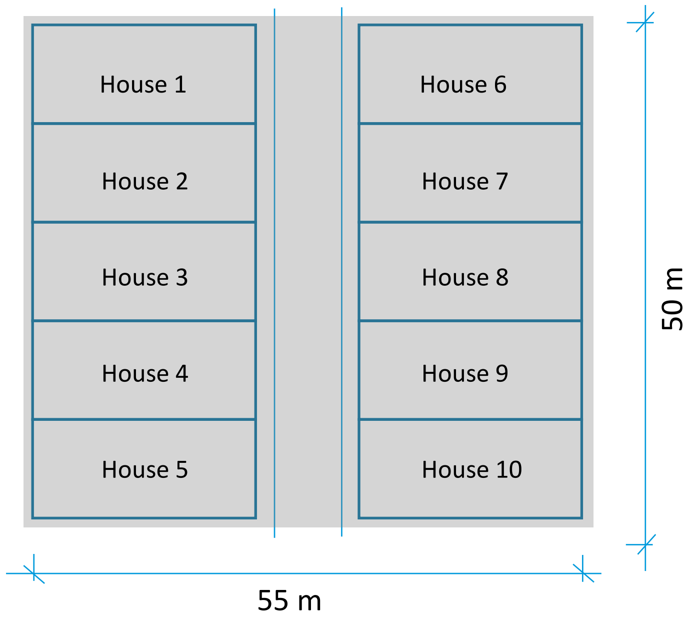
www.globalchange.umich.edu

Urbanization - Future Trends

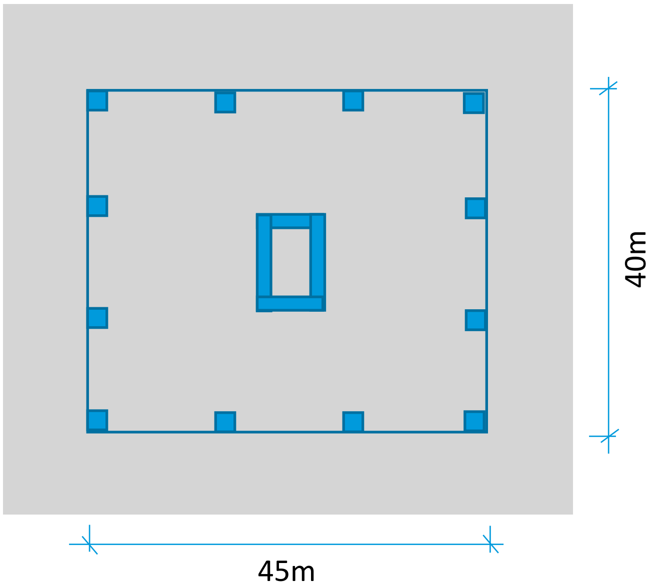


Source: www.globalchange.umich.edu


Urbanization → Growing Needs for built-up space



Versus

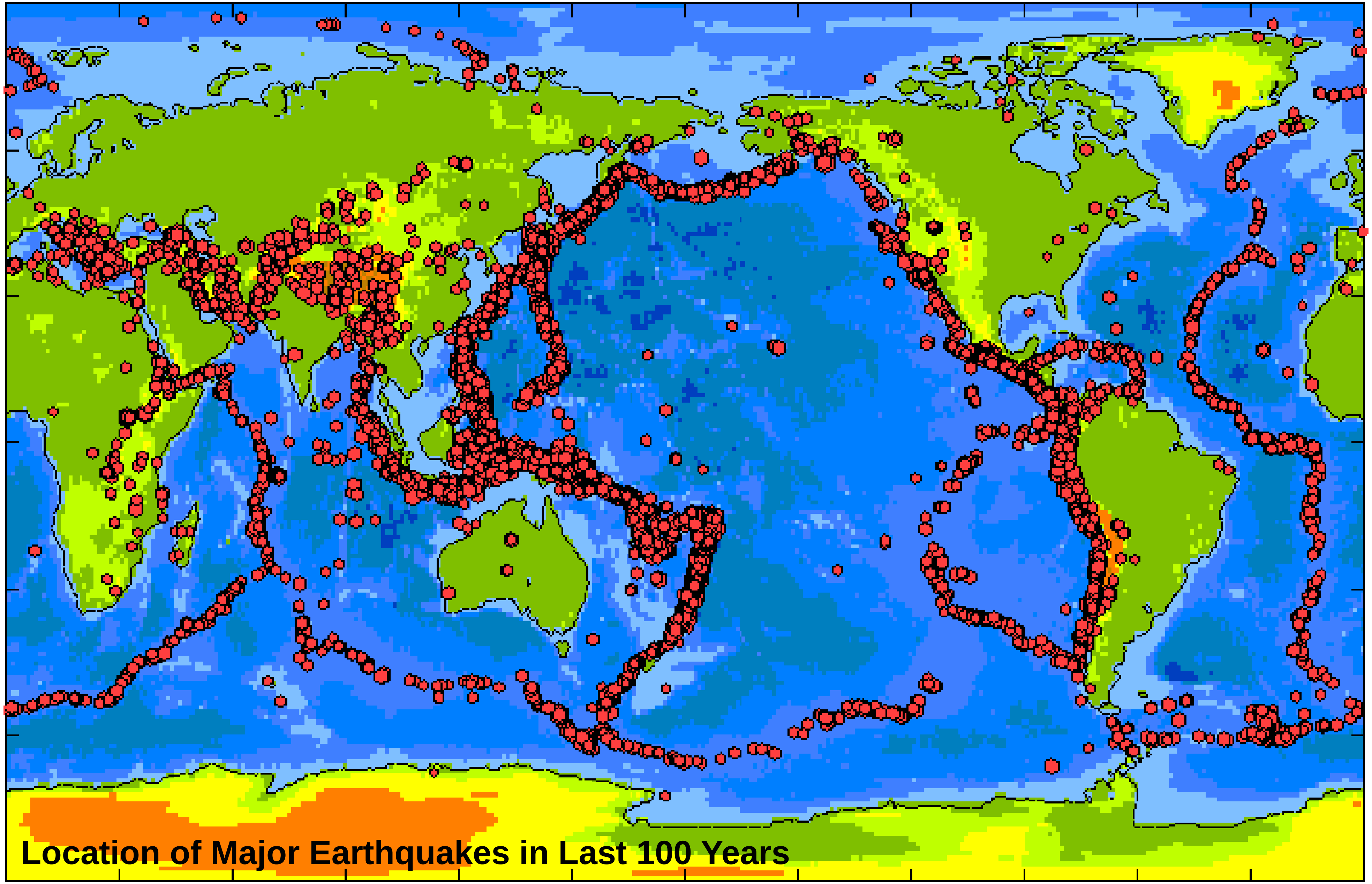


A Street of 10 small houses
(Accommodating 10 Families)

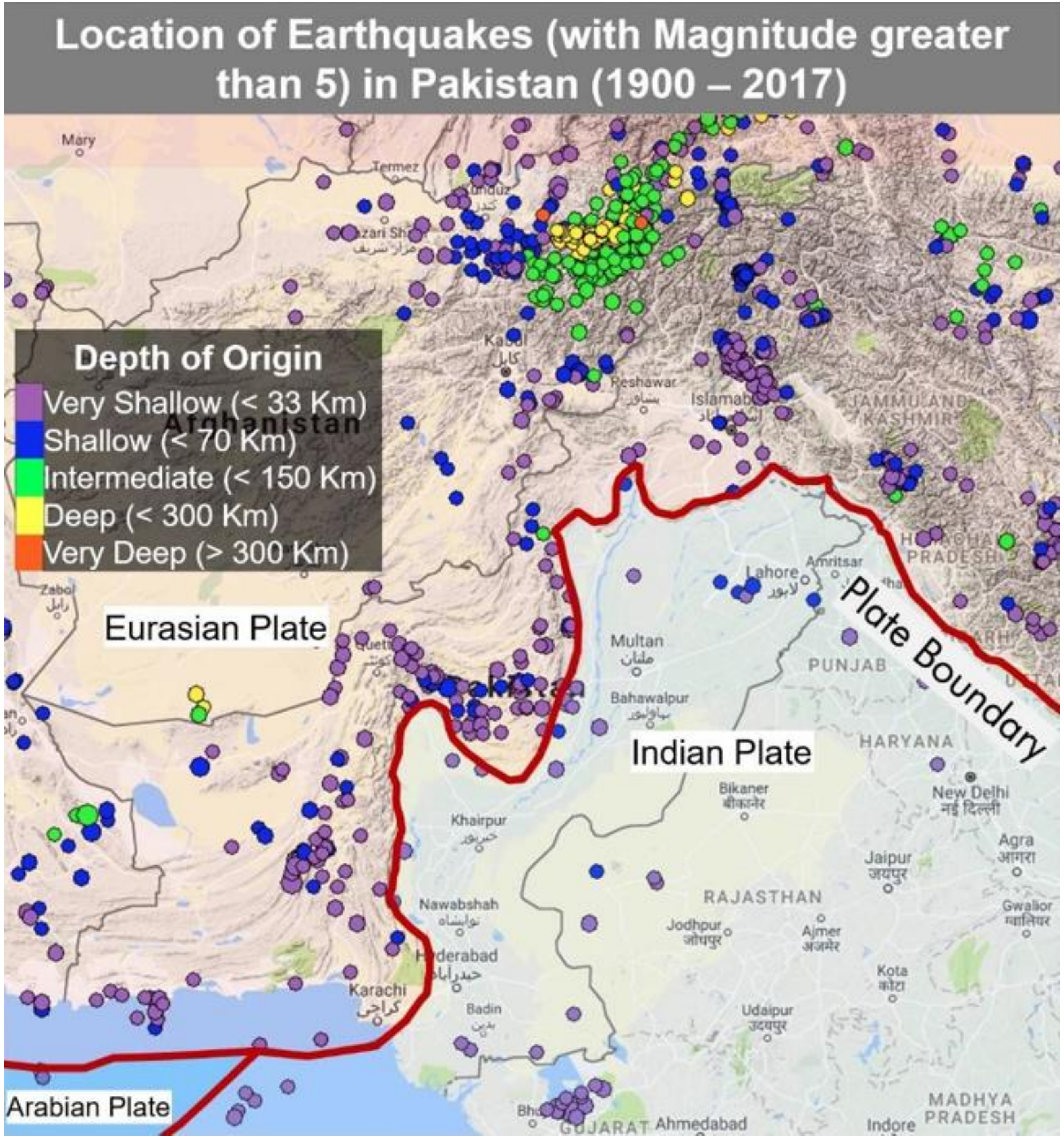
A 40 story Tall Building on almost same area
(Accommodating 200 Families)

London

Why This Course?



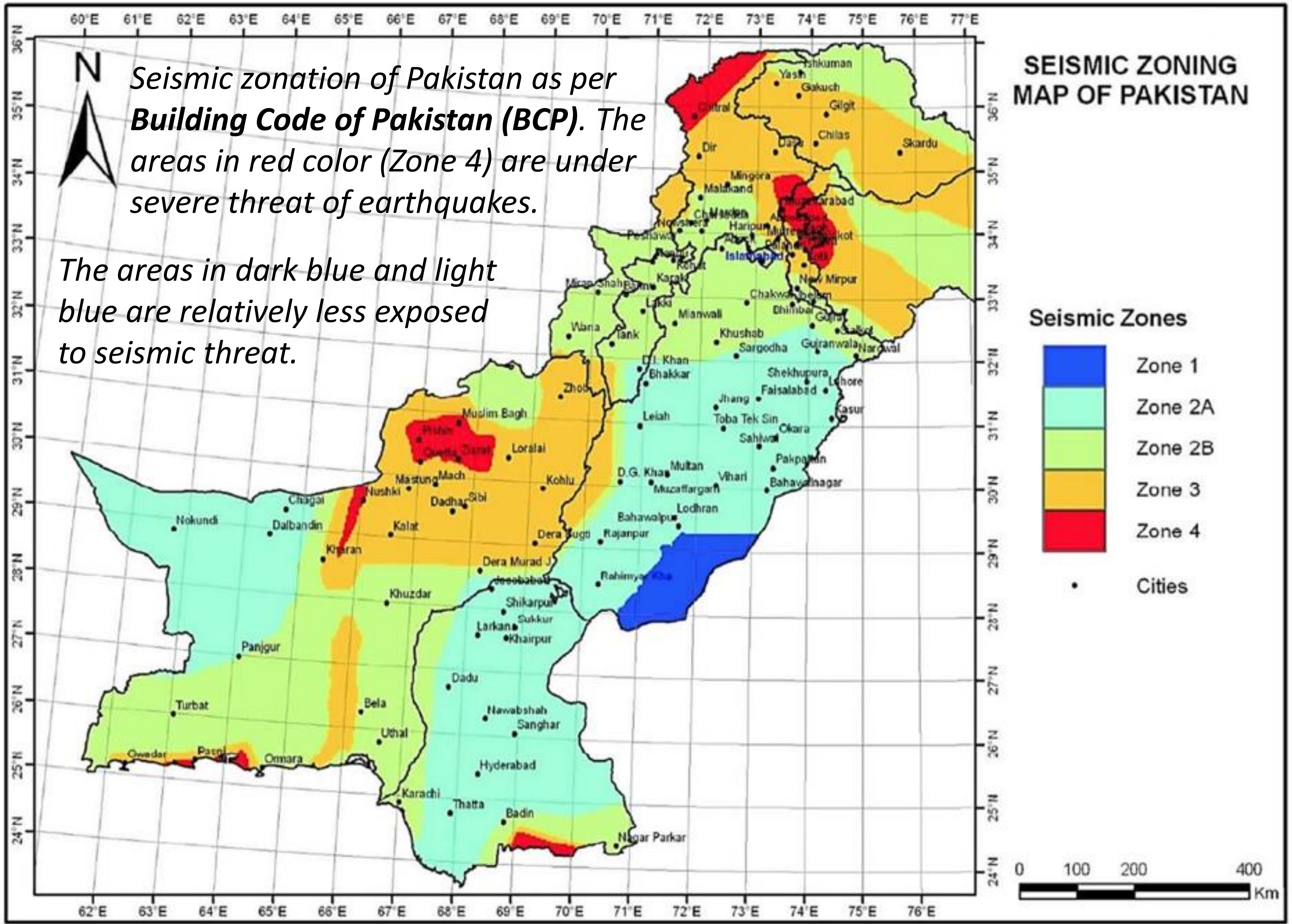
Seismicity of Pakistan



Why This Course?

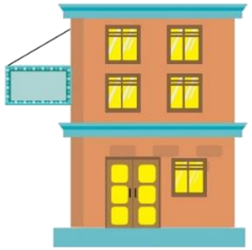
*Seismic zonation of Pakistan as per **Building Code of Pakistan (BCP)**. The areas in red color (Zone 4) are under severe threat of earthquakes.*

The areas in dark blue and light blue are relatively less exposed to seismic threat.

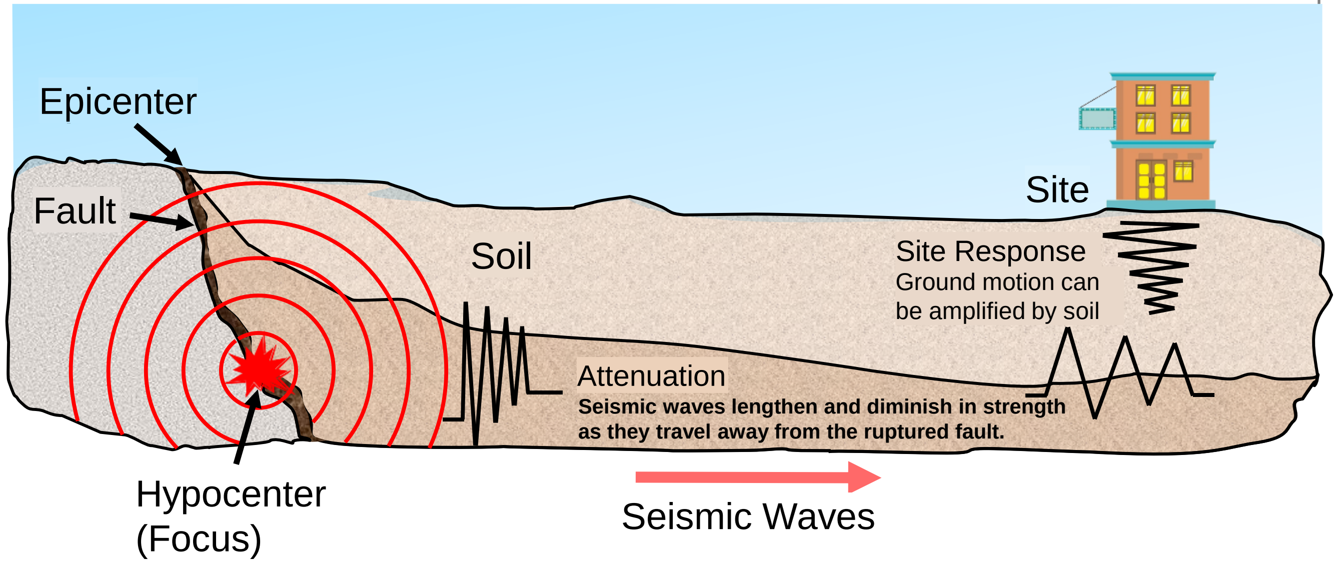


The Earthquake Problem

Structure



Future ground shaking



Linear/Nonlinear Analysis Model

Characterization of Seismic Ground Motions

Estimation of Linear/Nonlinear Seismic Demands

- Global-level Responses
- Inter-story Responses
- Component-level Responses

Why This Course?

- Pakistan is located on a highly earthquake-prone and seismically active part of the world.
- The country lies on a tectonically active Himalayan orogenic belt developed as a result of slow collision (extended over last 30-40 million years) among the Indian, Arabian, and Eurasian tectonic plates.
- This geological setting has resulted in a number of active seismic sources and faults in the region which are capable of producing moderate- to large-magnitude earthquakes.
- Besides having a high level of seismic hazard, the country is also confronted over the years with high rate of population increase and rapid growth of urbanization.
- With all these challenges and high seismic risk, there is an urgent need of equipping the civil engineering students with state-of-the-art information about seismic hazard, risk and its mitigation.
- This course aims to develop basic expertise and skill among the students about various practical aspects of seismic design of buildings and structures.

Motivations for Performance-based Design (PBD)

Motivations for PBD

- **Lack of explicit performance in design codes** is primary motivation for performance-based design.

- Performance based methods require the designer to assess how a building is likely perform in extreme events and their correct application will help to **identify unsafe designs**.

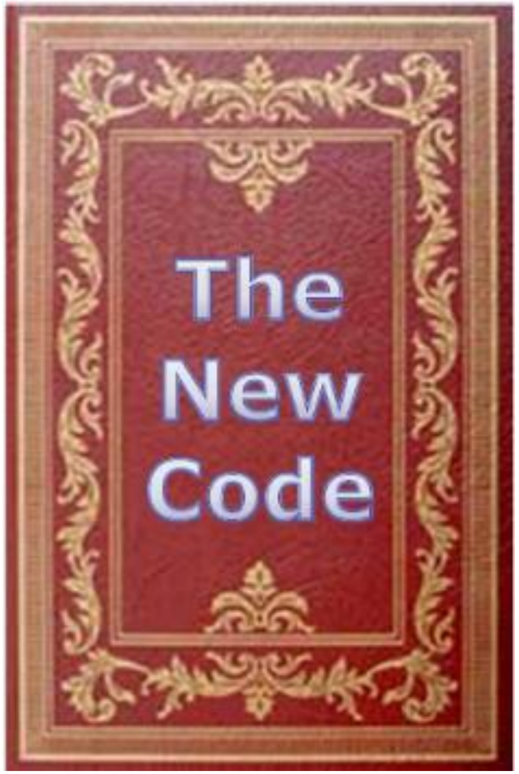
- Enables **arbitrary restrictions to be lifted** and provides scope for the development of innovative, safer and more cost-effective solutions.

Motivations for PBD

- In 1980 and 1990s (in the prevailing era of building codes), owners began to question **how their buildings would perform** in future earthquakes and demand that engineers design (or upgrade) their buildings to perform better.
- Owners usually express their desires in terms of a series of **performance objectives**.
  - I want my existing building to be safe etc. etc.
  - I want to be able to use my building right away.
  - I want the repair cost to be less than 20% of the replacement value.

Performance Based Design (PBD)

- **An approach in which structural design criteria are expressed in terms of achieving a set of performance objectives or levels.**
- Explicitly link the performance with earthquake hazard
- Ensures structures reaches specified demands level in both service and strength design levels.
- Why it was needed?
  - Traditional codes not suitable/adequate
  - Explicit verification not specified or required in most codes
  - Public does not care about the code, or theories or procedures, they care about "safety" and 'performance"



Prescriptive vs. Performance

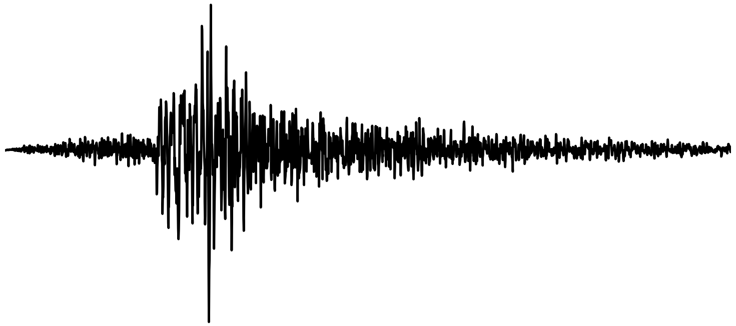
Approach	Procedure	Outcome
Prescriptive (emphasis on procedures)	Specify “what, and how to do” Make Concrete: 1:2:4	Implicit Expectation (a strength of 21 Mpa is expected)
Performance Based Approach (emphasis on KPI)	What ever it takes (within certain bounds)	Explicit Performance Concrete less than 21 Mpa is rejected

The Essence of PBD

- A *"decision-maker"* states a desire that a building be able to "perform" in a certain way.
  - Protect life safety
  - Minimize potential repair costs
  - Minimize disruption of use
- The *"engineer"* uses his or her skill to provide a design that will be capable of achieving these objectives.

Ron H. (2014), 2014 EERI Technical Seminar

Performance Objectives



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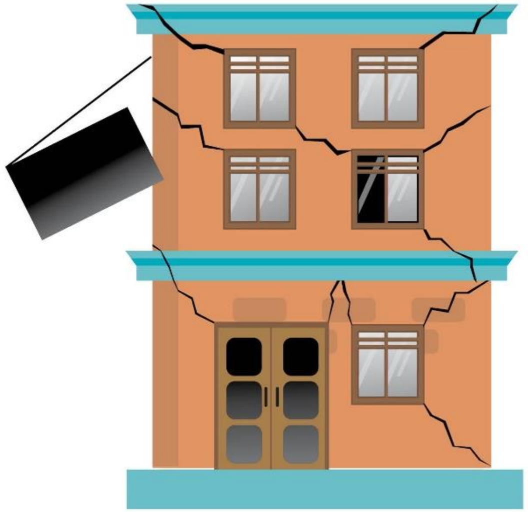


A Ground Motion

x% PE in 50 years

e.g. 2% PE in 50 years

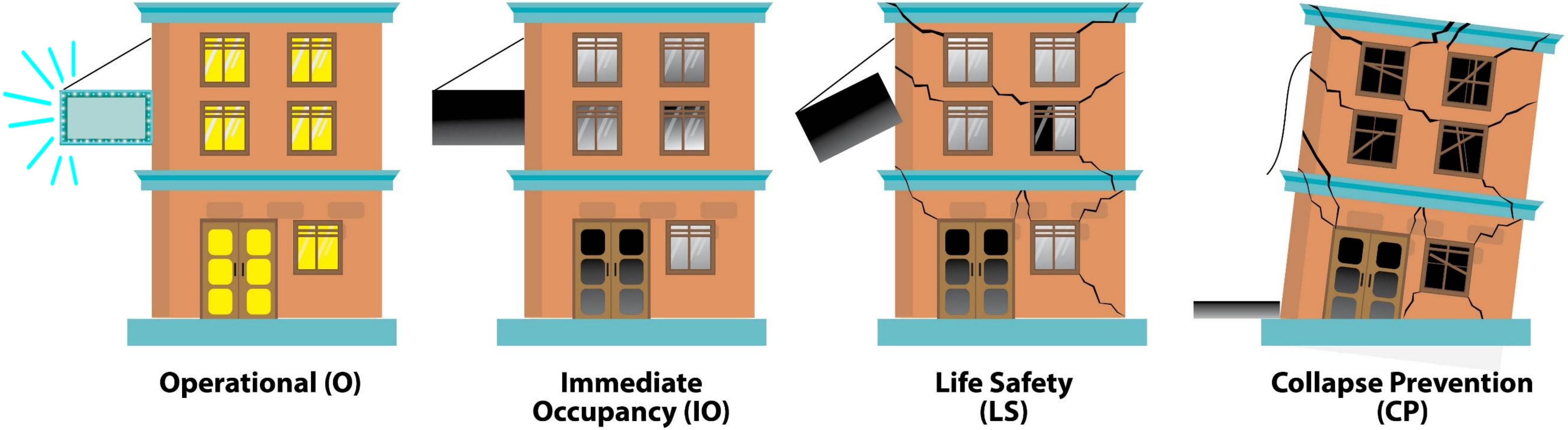
10% PE in 50 years

50% PE in 30 years

A Performance Level

Maximum acceptable damage, given that the ground motion occurs

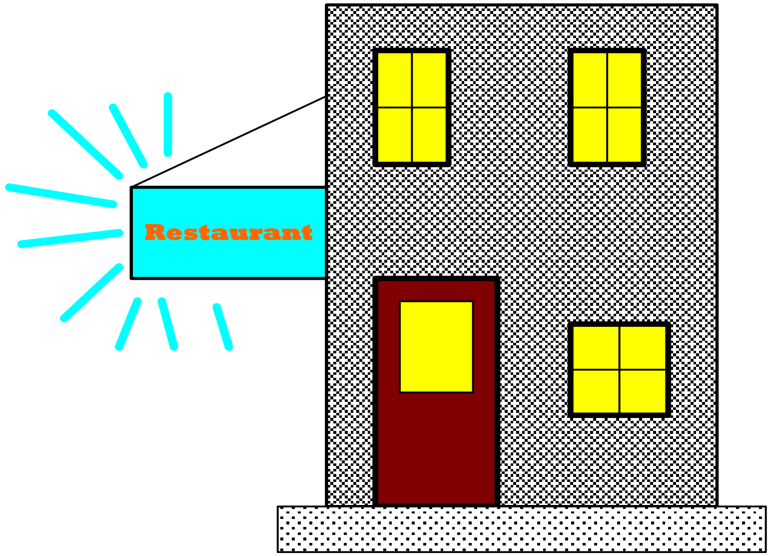
Performance Levels



Based on FEMA 451 B

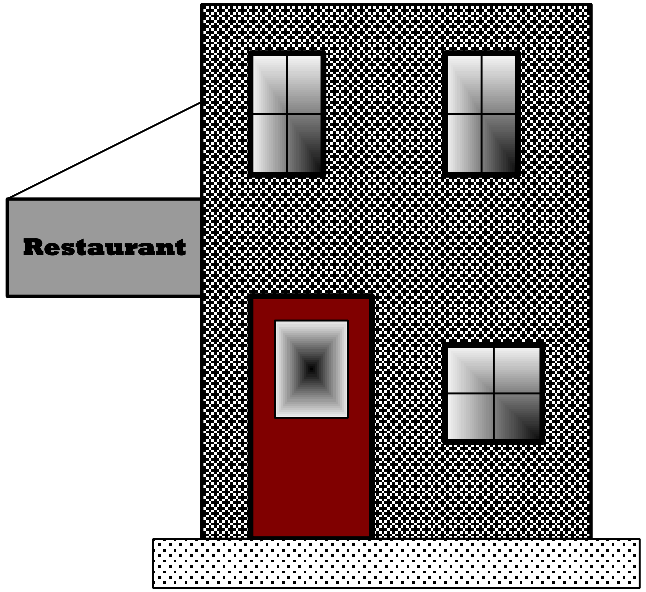
Operational Level

- Negligible structural and nonstructural damage
- Occupants are safe during event
- Utilities are available
- Facility is available for immediate re-use (some cleanup required)
- Loss < 5% of replacement value



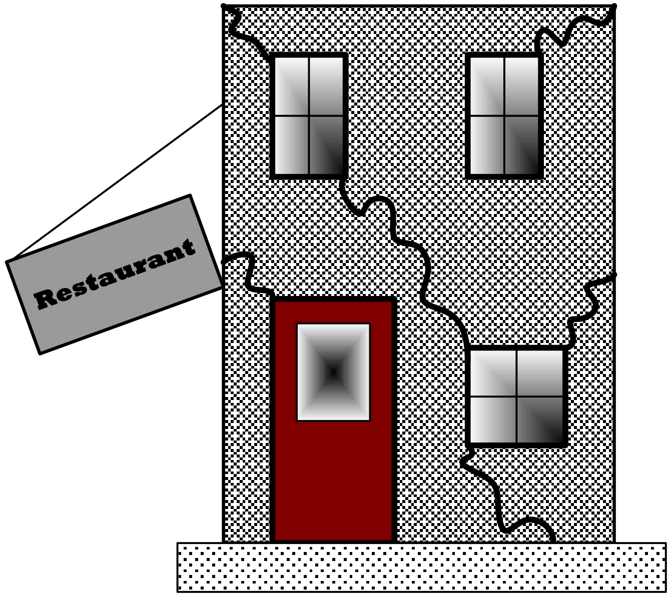
Immediate Occupancy Level

- Negligible structural damage
- Occupants safe during event
- Minor nonstructural damage
- Building is safe to occupy but may not function
- Limited interruption of operations
- Losses < 15%



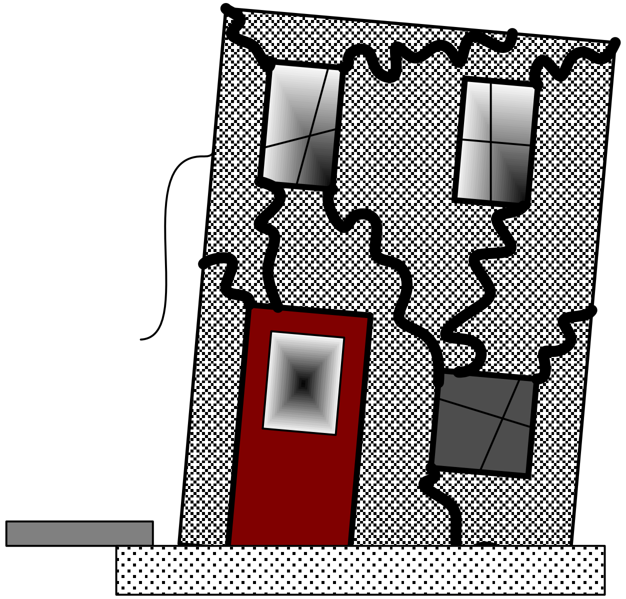
Life Safety Level

- Significant structural damage
- Some injuries may occur
- Extensive nonstructural damage
- Building not safe for re-occupancy until repaired
- Losses < 30%

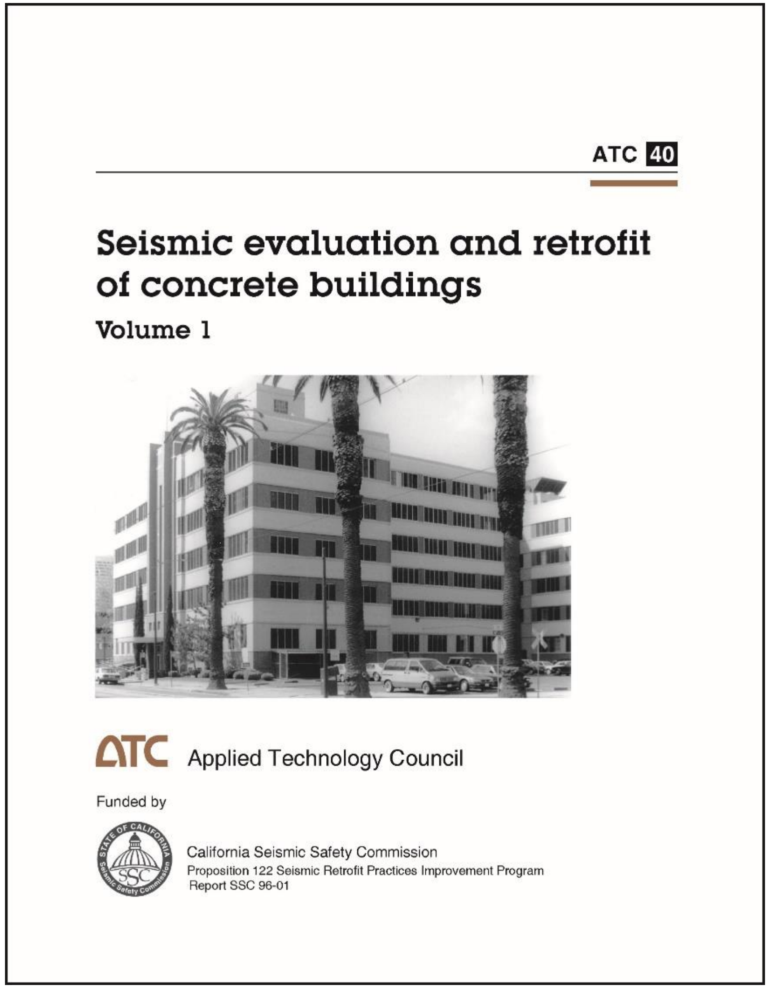


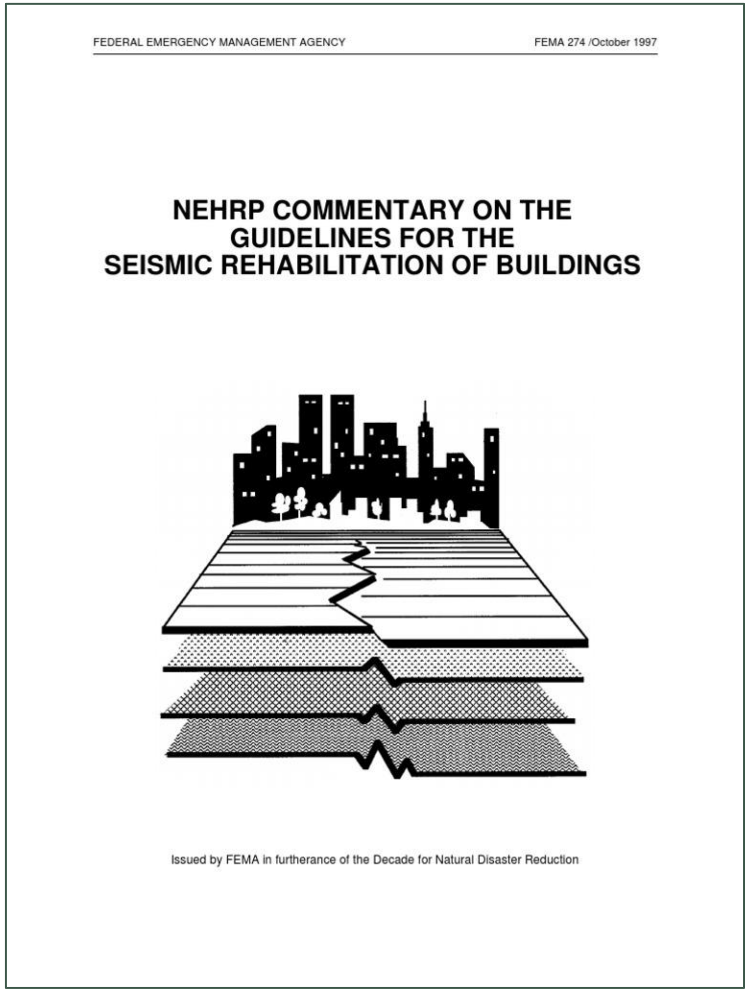
Collapse Prevention Level

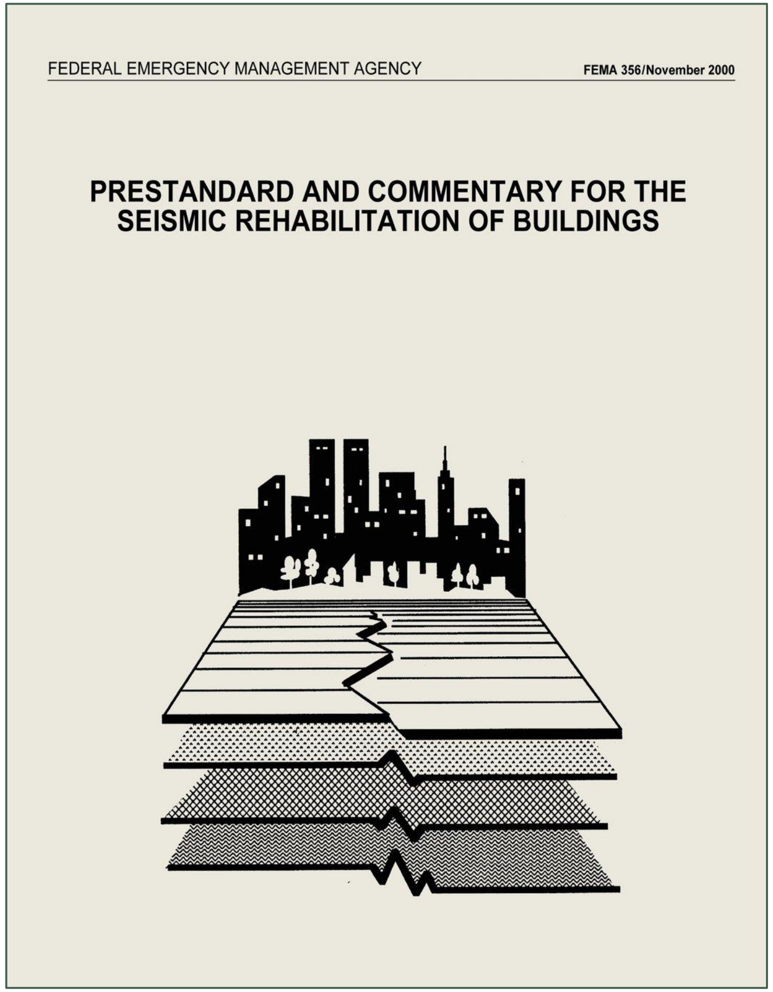
- Extensive (near complete) structural and nonstructural damage
- Significant potential for injury but not wide scale loss of life
- Extended loss of use
- Repair may not be practical
- Loss >> 30%



The First Generation of PBD Methodology

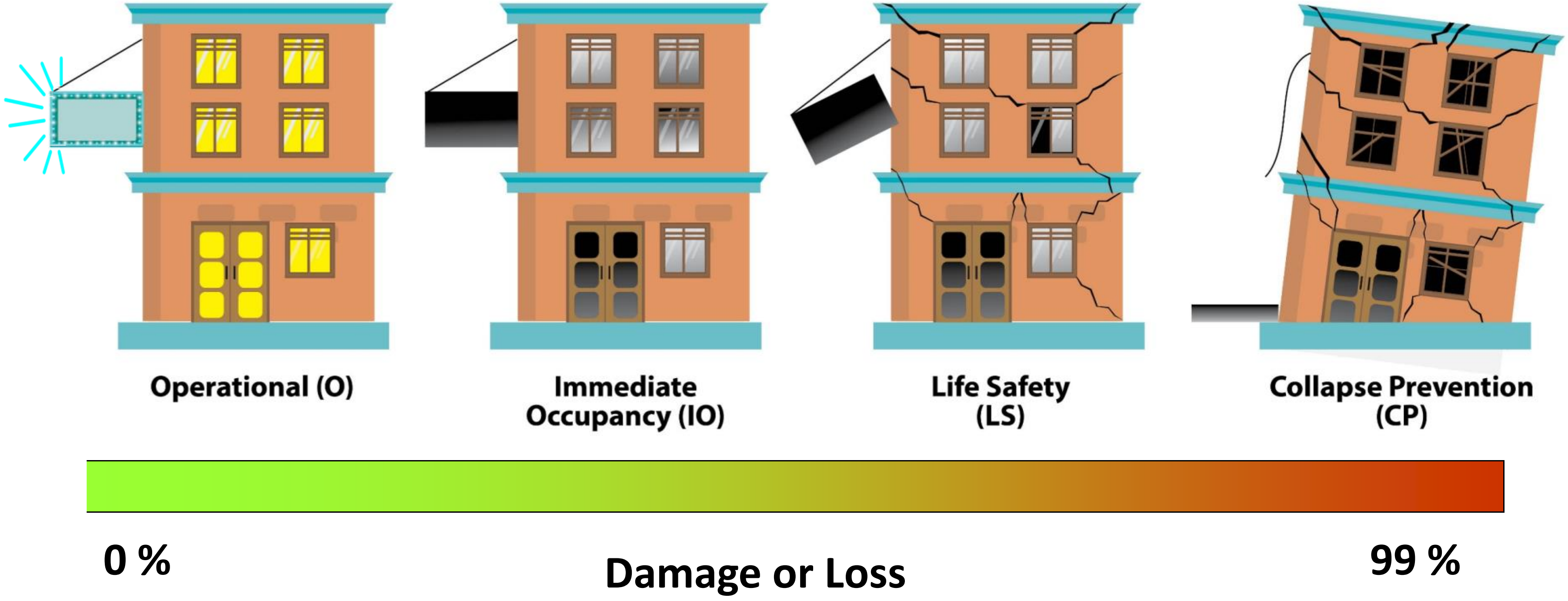






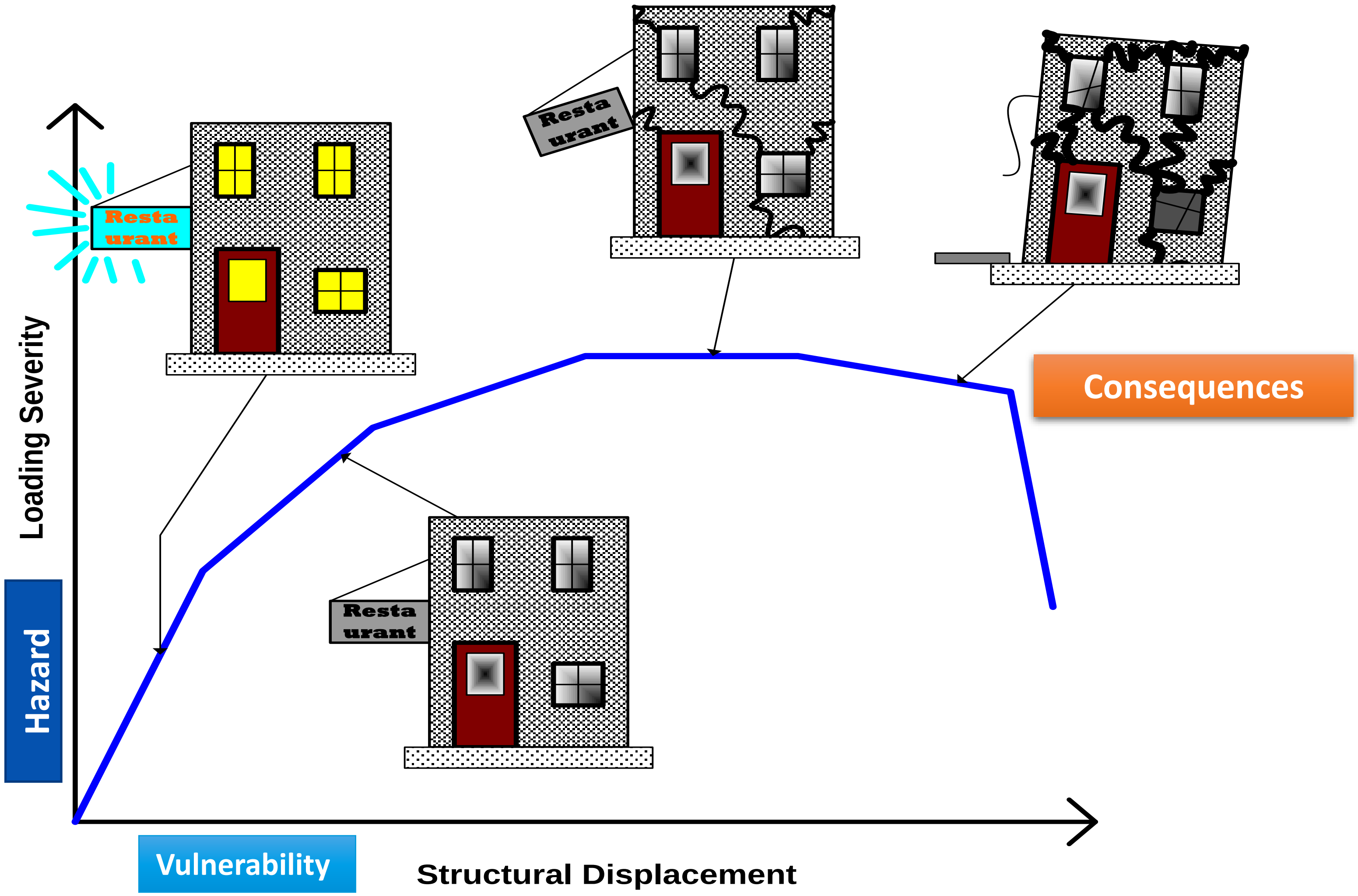
Nonlinear Analysis → Nonlinear Static (Pushover) Analysis

Standard Structural Performance Levels

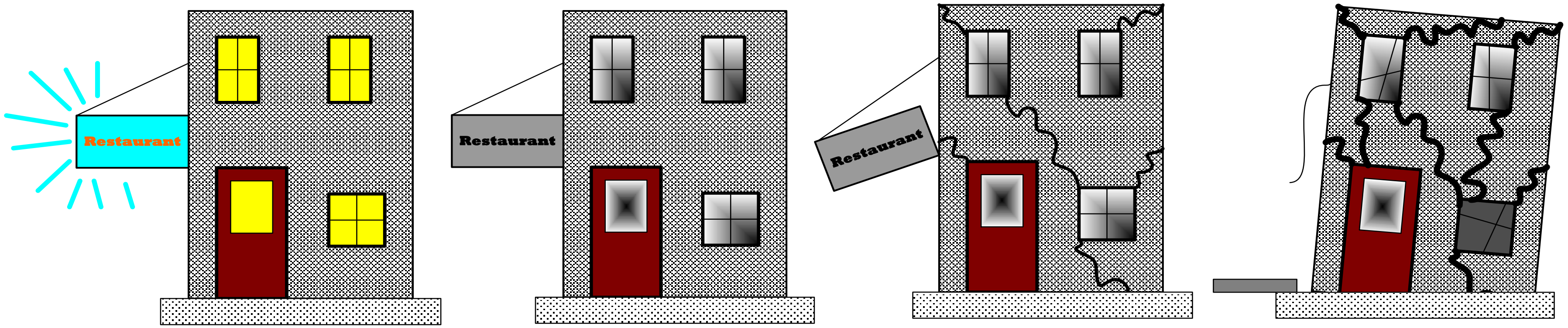


Ref: FEMA 451 B

Link the Hazard to Performance Levels



Link Performance to other Indicators



Operational (O) | Immediate Occupancy (IO) | Life Safety (LS) | Collapse Prevention (CP)

0 % — **Damage or Loss** — 99 %

Lowest — **Casualties** — Highest

Lowest — **Downtime for Rehab** — Highest

Lowest — **Rehab Cost to Restore after event** — Highest

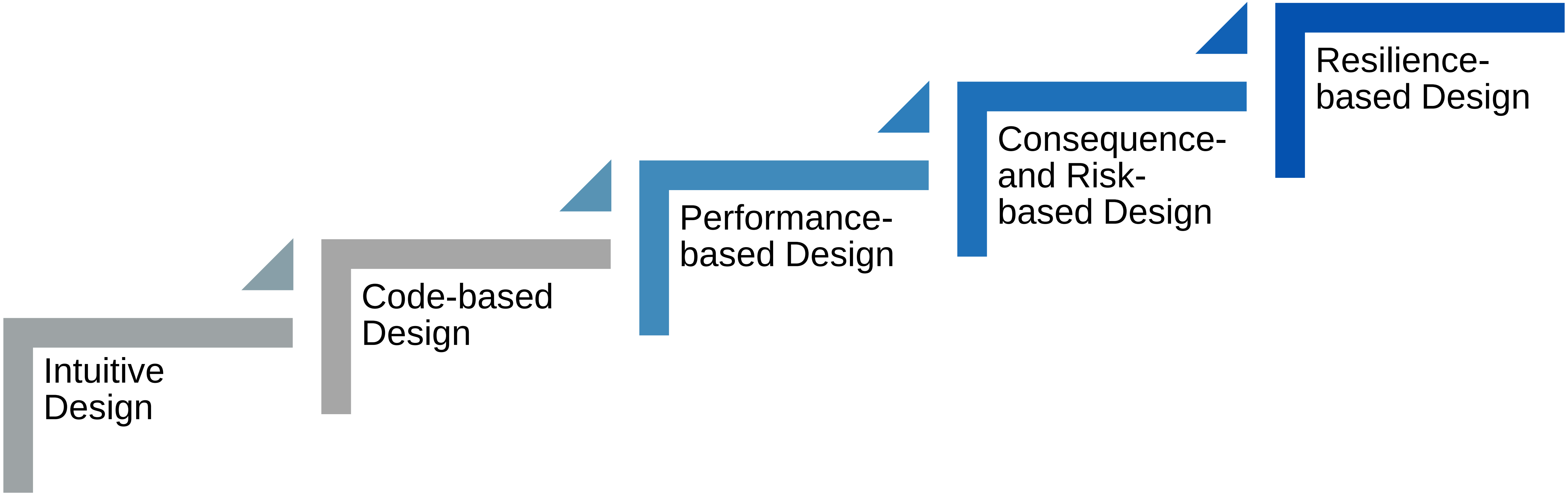
Highest — **Retrofit Cost to Minimize Consequences** — Lowest

Lowest — **Impact on Sustainability of Community** — Highets

Ref: FEMA 451 B

Performance-based design can be applied to any type of loads, but is typically suitable and targeted for earthquake loads

Evolution of Structural Design Approaches



Concepts Incorporated within PBD

- **Multiple** performance levels are checked.
- **Multiple** seismic events are applied.
- **May utilize nonlinear analysis.**
- Detailed local **acceptance criteria** and **element-by-element checking**.
    - For structural elements
    - For nonstructural elements

Definition of Seismic Hazard in Performance Based Design

- **Hazard:**
  - The intensity and characteristics of ground shaking that design is developed to resist.
- **Deterministic**
  - Magnitude “x” earthquake on “y” fault
  - Easy to understand but there is considerable uncertainty as to how strong the motion from such an event actually is.
- **Probabilistic**
  - “x” % probability of exceedance in “y” years for design event
  - Low intensity shaking occurs frequently.
  - Moderate intensity shaking occurs occasionally.
  - Severe shaking occurs rarely

Explicit Performance Objective in PBD

- Whereas traditional code procedures attempt to satisfy implicitly all three objectives by designing to prescriptive rules for a single (design) level of seismic hazard, performance based design of high rise buildings investigates **at least two performance objectives explicitly**
- 1) Service-level Assessment
  - Negligible damage in once-in-a-lifetime earthquake having a return period of about 50 years(30 years to 72 years depending on the jurisdiction and building importance)
- 2) Collapse-level Assessment
  - Collapse prevention under the largest earthquake with a return period of 2500 years

Explicit Performance Objective in PBD

Performance based design investigates at least two performance objectives explicitly

Service-level Assessment

Codes arbitrary "Design Level"

Collapse-level Assessment

Negligible damage with frequent hazards

(Earthquake having a return period of about 50 years)

Collapse prevention under extreme hazards

(the largest earthquake with a return period of 2500 years)

Performance Objectives

Level of Earthquake	Seismic Performance Objective
Frequent/Service (SLE): 50% probability of exceedance in 30 years (43-year return period)	Serviceability: Structure to remain essentially elastic with minor damage to structural and non-structural elements
Design Basis Earthquake (DBE): 10% probability of exceedance in 50 years (475-year return period)	Code Level: Moderate structural damage; extensive repairs may be required
Maximum Considered Earthquake (MCE): 2% probability of exceedance in 50 years (2475-year return period)	Collapse Prevention: Extensive structural damage; repairs are required and may not be economically feasible.

Performance Based Design Process

- Earthquake Hazard must be specified/ identified.
- For performance-based design to be successful, both the client and engineer must be satisfied.
- Engineer
    - Hazard must be quantifiable and performance must be quantifiable.
- Owner
    - Hazard must be understandable and performance must be understandable and useful.

Performance Level Definitions

Owner

- Will the building be safe?
- Can I use the building after the hazard?
- How much will repair cost in case of damage?
- How long will it take to repair?

Engineer

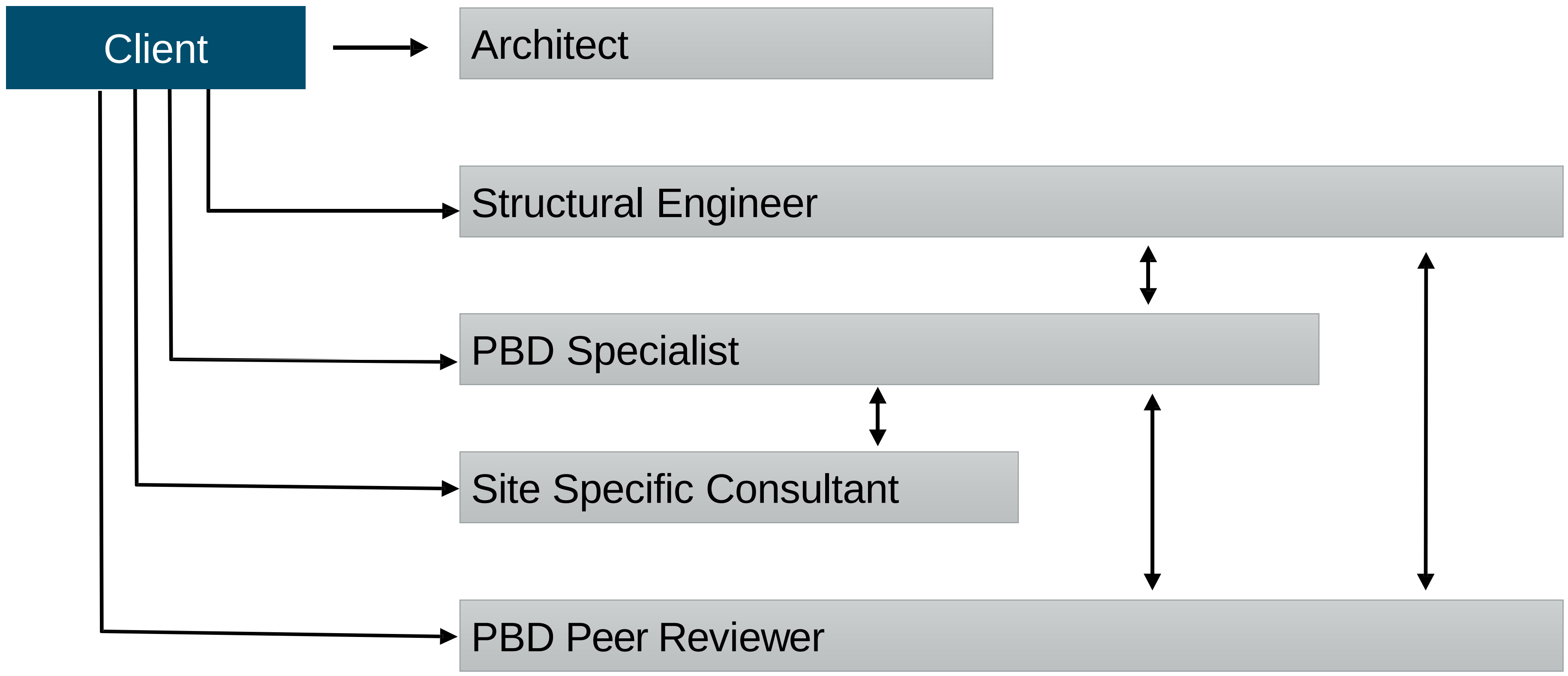
amount of yielding, buckling, cracking, permanent deformation, acceleration, that structure, members and materials experiences

Need a third party to ensure public safety and realistic Performance

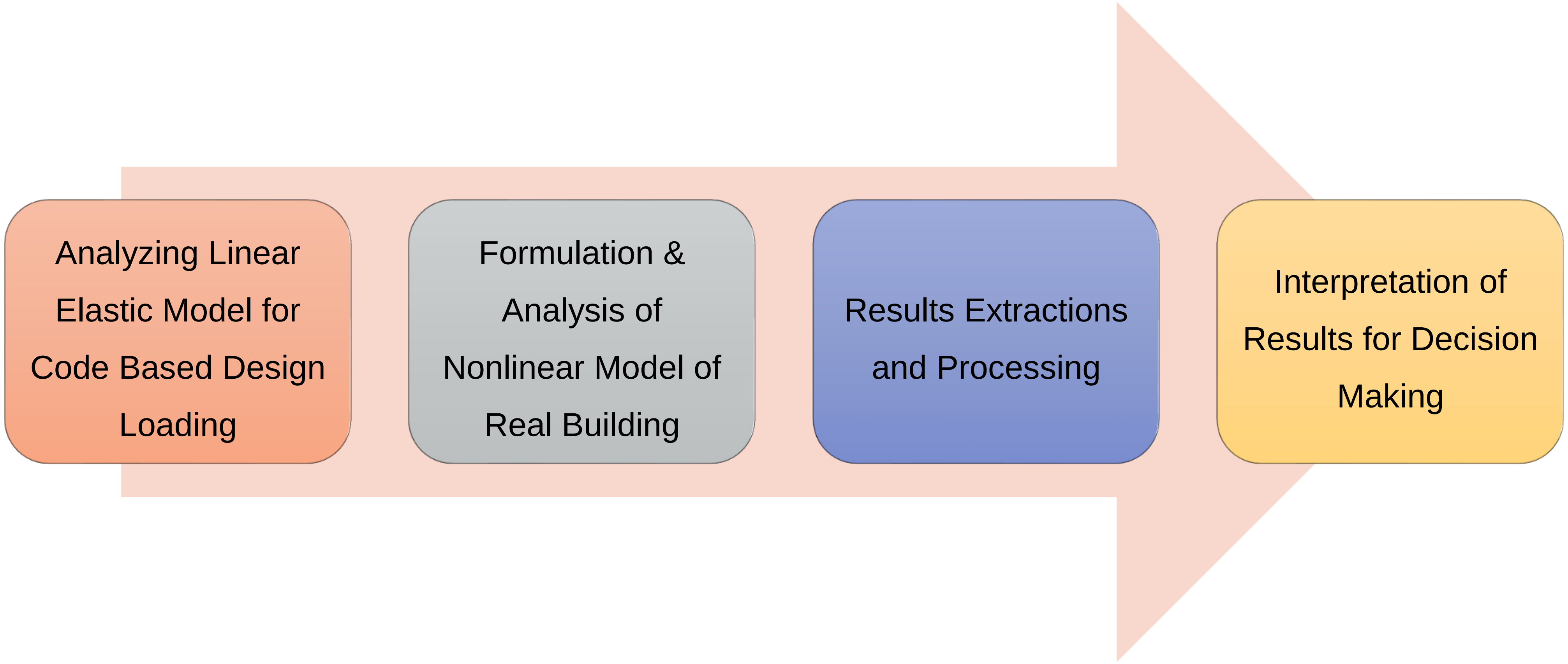
Guidelines

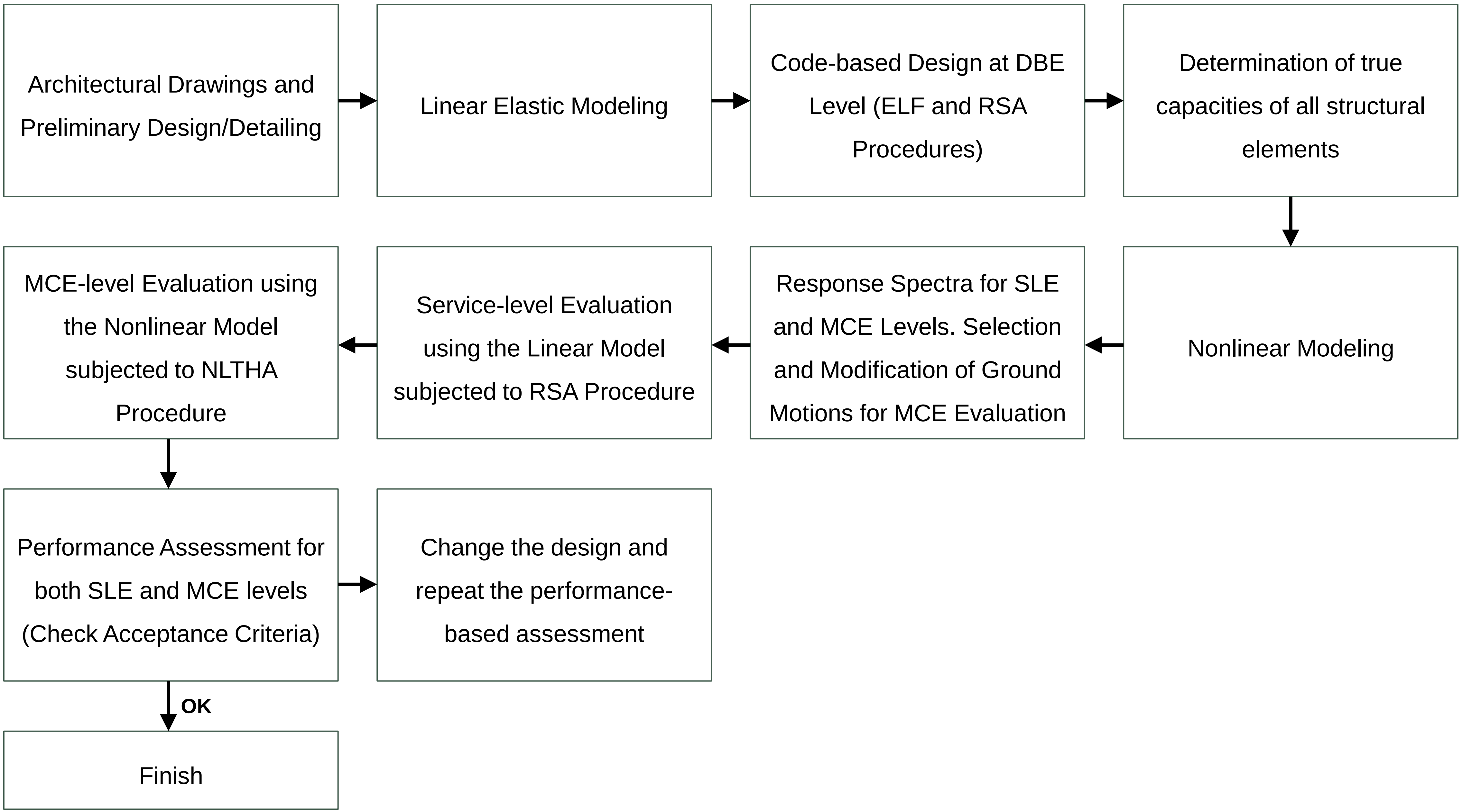
Peer Review

How to Work with PBD



Performance Based Design Process




Architectural Drawings and Preliminary Design/Detailing
Linear Elastic Modeling
Code-based Design at DBE Level (ELF and RSA Procedures)
Determination of true capacities of all structural elements
Nonlinear Modeling
Response Spectra for SLE and MCE Levels. Selection and Modification of Ground Motions for MCE Evaluation
Service-level Evaluation using the Linear Model subjected to RSA Procedure
MCE-level Evaluation using the Nonlinear Model subjected to NLTHA Procedure
Performance Assessment for both SLE and MCE levels (Check Acceptance Criteria)
Change the design and repeat the performance-based assessment
OK
Finish

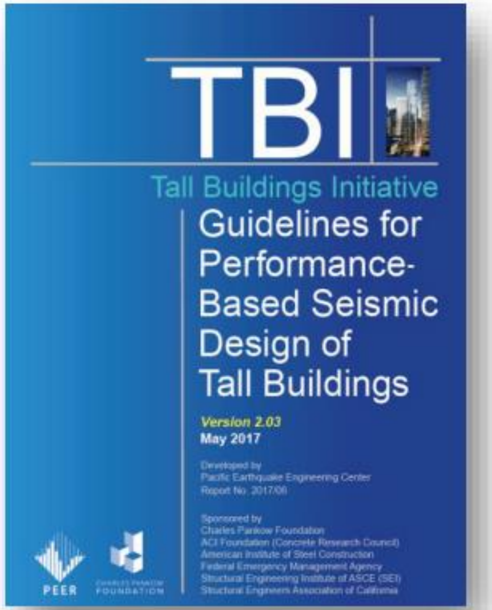
Pre-requisites for the PBD – Required Information

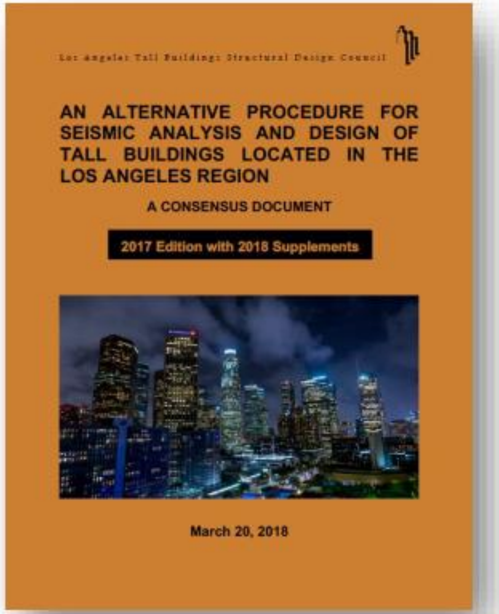
- **Basis of Design**
  - Description of building and structural system
  - Codes, standards and references
  - Loading criteria and references
  - Material properties
  - Modeling, analysis and design procedures
  - Performance objectives and acceptance criteria
- **Geotechnical Investigation**
  - SPT values
  - Soil stratification
  - Soil type for seismic analysis
  - Allowable bearing capacity
  - Sub-grade modulus
  - Liquefaction potential
  - Basement wall Pressure
- **Site-specific Probabilistic Seismic Hazard Assessment**
  - Hazard evaluation
  - Ground motion parameters
  - SLE, DBE and MCE spectra
- **Wind Tunnel Testing**
  - 10-year return period wind load
  - 50- and 70-year return period wind load
  - Floor accelerations (1-year and 5-year return periods)
  - Rotational velocity (1-year return period)
  - Natural frequency sensitivity study

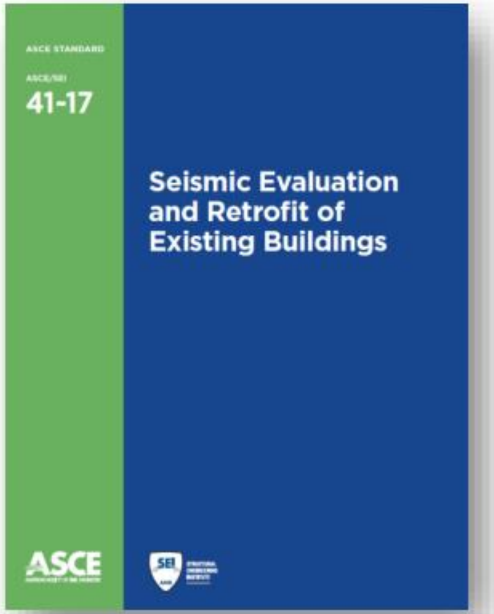
Reference: Mr. Aung Htut Thaung
(AIT Solutions, Thailand)

Special Purposes Guidelines for PBD

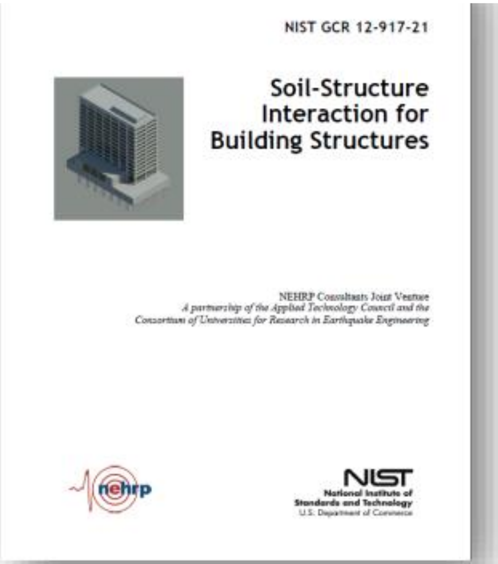
- Applied Technology Council (ATC)
- Federal Emergency Management Agency (FEMA)
- National Earthquake Hazards Reduction Program (NEHRP)
- PEER Guidelines for Tall Buildings
- Tall Buildings Initiatives (TBI)
- CTBUH Guidelines

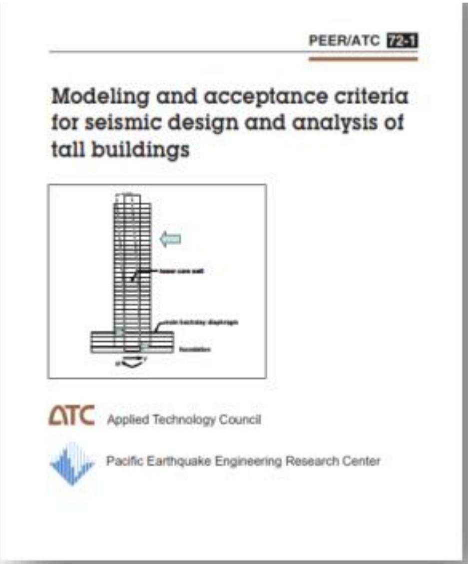


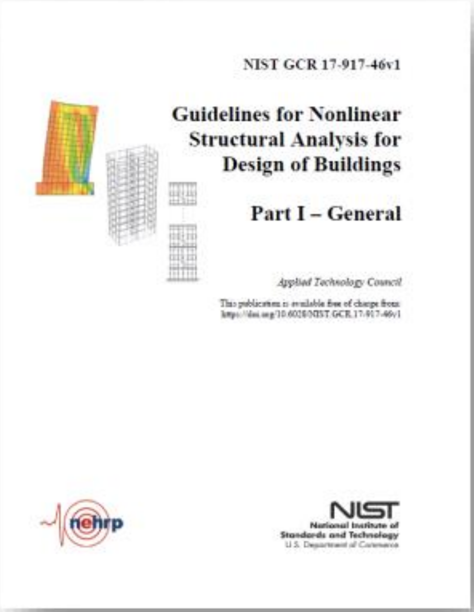




Nonlinear Analysis → Nonlinear Dynamic Analysis







Course Contents

Blue = Topics to be covered. They will be explained in a self-contained manner and NO additional lectures (or videos) will be required to understand them.

Black = Already available (and helpful) topics/videos for additional study but NOT necessary to watch/learn for this course.

Topic 1: Understanding the Seismic Hazard

- Basics of Seismology and Seismic Hazard Assessment
  - Basic Seismology
  - Introduction to Seismic Hazard Analysis
  - ► Playlist Title: Basics of Seismology and Seismic Hazard Analysis

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9Suz9jXXagM9fD_N0mPCrH
- Concepts of Spectral Acceleration and Response Spectrum
  - Site-specific Response Spectrum
  - Design Spectrum in Building Codes
  - ► Videos 14 to 19 of the following playlist.

    Playlist Title: Basics of Structural Dynamics and Earthquake Engineering

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq81ONOaHIaWiQB8Tu7W0N0D

Course Contents

Topic 2: Code-based Seismic Analysis and Design Procedures (IBC 2021 and ASCE 7-16)

- A Step-by-step IBC Approach to the Seismic Analysis and Design
- A Quick Review of all Seismic Analysis Procedures
- Equivalent Lateral Force Procedure
  - ► Playlist Title: The Equivalent Lateral Force (ELF) Procedure for the Seismic Analysis and Design of Building Structures

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq90Pe--dkaJZK1TFrebzHqW
- Response Spectrum Analysis Procedure
  - ► Playlist Title: The Response Spectrum Analysis (RSA) Procedure for the Seismic Analysis and Design of Building Structures

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq8BHAwRxoXq5t1WWAofYvB_
- Linear Time History Analysis Procedure
  - ► Playlist Title: The Linear Time History Analysis (LTHA) Procedure for the Seismic Analysis and Design of Building Structures

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9ugthkYZ7YGI8pxu0nOFxy
  - ► Video Lecture: Selection and Modification of Ground Motion Records for the (Linear or Nonlinear) Response History Analysis of Structures.

    Link: https://www.youtube.com/watch?v=xwEQpsadIpE

Course Contents

Topic 3: An Introduction to BCP 2022 – Shifting from UBC 1997 to IBC 2021: Implications and Challenges

Topic 4: Capacity Design and Ductility Design of Structures

Topic 5: Introduction to Performance-based Design Approach

- PBD Basics and Methodology, Structural Performance Levels and Acceptance Criteria
  - ► Videos 1 to 6 of the following playlist.
    Playlist Title: Nonlinear Modeling and Analysis for Performance-based Seismic Design of Structures
    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9nHPl6jtYbB9aTjxBLTi3l
  - ► PSCE Technical Lecture 25: The Scope of Performance-based Seismic Design of Structures in Pakistan
    Link: https://www.youtube.com/watch?v=uxgNawJh3V8
  - ► PSCE Technical Lecture 32: Issues and Challenges in Earthquake Risk Reduction in Pakistan
    Link: https://www.youtube.com/watch?v=AOJ3-v8ESS8
- Tall Buildings Initiative (TBI) Guidelines for Performance-Based Seismic Design of Tall Buildings (2017)
  - Ground Motion Characterization in Performance-based Design
  - Modeling and Analysis
  - Service-Level Earthquake (SLE) Evaluation
  - Maximum Considered Earthquake (MCER) Evaluation

Course Contents

Topic 6: Nonlinear Modeling and Behavior of Building Structures

- A Quick Overview of Linear Elastic Modeling (+ A Hands-on Training on ETABS 2016)
  - ► Playlist Title: Lecture Series on Modeling for Linear Elastic Analysis of Structures [Duration: 17 Hours]

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9WzNWSgbv44KoAASXukGXe
- Fundamentals of Nonlinear Modeling – Distributed and Lumped Plasticity Approaches – Hysteretic Behaviors, Strength Loss, Cyclic Degradation
  - ► Videos 7 to 13 of the following playlist.

    Playlist Title: Nonlinear Modeling and Analysis for Performance-based Seismic Design of Structures

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9nHPl6jtYbB9aTjxBLTi3l
- CSI ETABS Demonstration on Fiber Modeling Approach and Plastic Hinge Modeling Approach
  - ► Videos 14 to 30 of the following playlist.

    Playlist Title: Nonlinear Modeling and Analysis for Performance-based Seismic Design of Structures

    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9nHPl6jtYbB9aTjxBLTi3l
- Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)

Course Contents

Topic 7: Nonlinear Dynamic Analysis of Buildings for MCER Evaluation

- Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)
- Interpreting the Dynamic Response and Seismic Performance of Buildings, Understanding the Analysis Results from Nonlinear Time History Analysis

Topic 8: Performance Evaluation of Individual RC Components

- RC Beams and Columns
- RC Shear Walls
- RC Foundations
- RC Diaphragms

Topic 9: Structural Performance and Cost Optimization

Topic 10: Presentation of Results of Performance-based Seismic Evaluation

Content and Lecture Plan (Spring 2022)

Optional Topics (One or two topics may be covered if time allowed):

- Direct Displacement-based Seismic Design (DDBD) of Structures
- Nonlinear Static Procedures, NSPs (Pushover Analysis Procedures)
- Introduction to First-mode based Conventional Pushover Analysis Procedures (Capacity Spectrum Method, Displacement Coefficient Method)
  - ► Playlist Title: Lecture Series on Miscellaneous Topics (with ETABS Demonstrations)
    Part 1: https://www.youtube.com/watch?v=JY8Z2fgZ9eM
    Part 2: https://www.youtube.com/watch?v=d08WgWEVXjI
  - ► Playlist Title: Pushover Analysis of Building Structures
    Link: https://www.youtube.com/playlist?list=PL48SKuieCUq9zEKP0vyLXQQsBNmOT1ydx
- Introduction to Modal Pushover Analysis (MPA) Procedure and Uncoupled Response History Analysis (UMRHA) Procedure
- Soil-Structure Interaction
- Site Response Analysis and Site Amplification Effects
- Seismic Vulnerability Assessment of Buildings and Structures
- Seismic Loss Estimation of Structural and Non-structural Components

Who Should Attend?

- The expected audience for this course includes the following.
  - Masters and Ph.D. students
  - Structural designers, practicing engineers and consultants
  - Architects, planners
  - Real-estate developers and owners

Textbooks References and Reading Material

- Textbook
  - Lecture notes provided by instructor
- Reference Books

1) T. Pauley, and M. J. N. Priestley, (1992): Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley and Sons, New York.
2) A. K. Chopra, (1995): Dynamics of Structures-Theory and Applications to Earthquake Engineering, Prentice Hall, New Jersey.
3) R. W. Clough, and J. Penzien, (1993): Dynamics of Structures, McGraw-Hill, New York, 2nd Edition.
4) J. W. Smith, (1988): Vibration of Structures: Applications in Civil Engineering Design, Chapman and Hall, London.
5) W. F. Chen and C. Scawthorn (2003), Earthquake Engineering Handbook.
6) T. Y. Lin and S.D. Stotesbury (1988): Structural Concepts and Systems for Architects and Engineers, 2nd edition, Van Nostrand Reinhold.
7) Graham H. Powell (2010): Modeling for Structural Analysis, Computers & Structures Inc.
8) Edward L. Wilson (2000): Three-Dimensional Static and Dynamic Analysis of Structures, Computers & Structures Inc.
9) Tall and Super-tall Buildings: Planning and Design (2014): Editor: Akbar Tamboli, Publisher: McGraw-Hill Professional, with CTBUH and ICC, ISBN13: 978-0071818711 ISBN: 0071818715
10) James K. Wight (2016): Reinforced concrete: Mechanics and design, 7th edition, Prentice Hall.
11) E. G. Nawy (2009): Reinforced concrete: A Fundamental Approach, 6th edition, Prentice Hall International
12) Arthur H. Nilson, David Darwin, Charles W. Dolan (2005): Design of Concrete Structures, 13th Edition.
13) Bungale S. Taranath (2010): Reinforced Concrete Design of Tall Buildings, Taylor and Francis Group, LLC.

Textbooks References and Reading Material

- International Standards/Guidelines

    1) TBI (2010): Guidelines for Performance-Based Seismic Design of Tall Buildings - PEER
    2) FEMA 356 (2000): Pre-standard and Commentary for the Seismic Rehabilitation of Buildings
    3) ATC-40 (1996) Seismic Evaluation and Retrofit of Concrete Buildings, USA
    4) ASCE/SEI 41-13 (2014): Seismic Rehabilitation of Existing Buildings (ASCE/SEI 41-13)
    5) Council on Tall Buildings and Urban-Habitat (2008): Recommendations for the Seismic Design of High-Rise Buildings.
    6) PEER/ATC-72-1 (2011): Modeling and Acceptance Criteria for Tall Buildings, USA
    7) ASCE 7-16 (2017): Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-16)

Textbooks References and Reading Material

- Research Journals

  1) Earthquake Engineering & Structural Dynamics, Wiley
  2) Engineering Structures, Elsevier
  3) The Structural Design of Tall and Special Buildings
  4) Soil Dynamics and Earthquake Engineering, Elsevier
  5) Journal of Structural Engineering, ASCE
  6) ACI Structural Journal, ACI7)
  7) Structural Engineering International Journal, IABSE
  8) Magazine of Concrete Research, ICE

Internet Resources

- Learning Resources
  - http://peer.berkeley.edu/
  - https://www.fema.gov/
  - www.ctbuh.org
  - www.structuralengineering.info
  - https://earthquake.usgs.gov/
  - http://www.iris.edu/hq/
  - http://ds.iris.edu/ieb/

- Major Ground Motion Databases
  - USGS Earthquake Catalog
    - ✓ https://earthquake.usgs.gov/earthquakes/search/
  - PEER Ground Motion Database
    - ✓ https://ngawest2.berkeley.edu/site
  - British Geological Survey Database
    - ✓ http://quakes.bgs.ac.uk/
  - COSMOS Ground Motion Data Center
    - ✓ http://strongmotioncenter.org/vdc/scripts/default.plx
    - ✓ http://www.cosmos-eq.org/
  - K-NET and KiK-net, the NIED Strong-motion Seismograph Network Database
    - ✓ http://www.kyoshin.bosai.go.jp/

Internet Resources

- Magazines/Articles
  - ✓ http://www.structuremag.org/
  - ✓ https://www.istructe.org/thestructuralengineer
  - ✓ http://ctbuh-korea.org/ijhrb/index.php
  - ✓ https://www.express.pk/story/968021/
  - ✓ http://www.technologyreview.pk/the-science-of-earthquakes/
  - ✓ http://www.technologyreview.pk/12-years-october-earthquake-pakistan-prepared-handle-another-big-one/

Internet Resources

- Video Playlists
  - Nonlinear Modeling and PERFORM 3D Seminar by Graham H. Powell
    Description: Four valuable sessions on nonlinear modeling of structural components + Hands-on training sessions PERFORM 3D.
    Link: Will be provided by instructor

  - Title: “PBD Seminar and Workshop” – AIT Solutions (Youtube Channel)
    Description: International Seminar and Workshop on Performance Based Design of Reinforced Concrete Buildings - 27-28 August 2013 - Hosted by the Asian Center for Engineering Computations and Software (ACECOMS) in collaboration with AIT Consulting.
    Link: https://www.youtube.com/playlist?list=PLVjfkNRH6tRfSEM1vPIgKeL3tA7PQFAPE

  - Computers and Structures, Inc. (Youtube Channel)
    Description: CSI Watch and Learn Video Tutorials
    Link: https://www.youtube.com/user/computersNstructures

  - International Seminar on Design of Tall Buildings – November 2016 (Bangkok)
    Description: Hands-on training sessions of different finite element modeling and analysis software (SAP, ETABS, SAFE and PERFORM 3D)
    Link: Will be provided by instructor

Grading Scheme and Instructor

- Grading Scheme

Assignments + Quizzes	20%
OHT Exams	30%
Term Project	10%
ESE	40%
Total	100%

- Instructor

Dr. Fawad Ahmed Najam

Assistant Professor (Structural Engineering)

NUST Institute of Civil Engineering (NICE)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST)

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Cell: 92-334-5192533, Email: fawad@nice.nust.edu.pk

Office No: 014, Ground Floor, NIT Building, SCEE, NUST

www.fawadnajam.com/pbd-nust-2022/

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Home / CE – 842 Performance-based Seismic Design of Structures

NUST institute of Civil Engineering (NICE)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST)

H – 12, Islamabad, Pakistan

Course Overview | Lectures & Notes | Assignments | Tests & Exams | Learning Resourses

CE - 842: Performance-based Seismic Design of Structures

Description and Rationale

With recent advances in computing and modeling tools, and with growing challenges in terms of increase in population, urbanization, complexities in structural forms and innovative systems, the practicing structural engineers and designers nowadays need to equip themselves with various advanced skills. The demand and complexity is rapidly increasing for built environment including accommodation, offices, and commercial areas to accommodate rapidly growing urban population. Resultantly, the cities and infrastructure of future will need to be denser, complex and taller. These challenges require great expertise and computational capabilities in terms of using state-of-

Thank you for your attention