NUST institute of Civil Engineering (NICE)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences and Technology (NUST)

PG 2021 Batch	Code/Course: CE - 842
Semester: Spring 2022	Course Title: Performance-based Seismic Design of Structures
Credit Hours: 03	Pre-requisites: Nil

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-the-art nonlinear analysis procedures, latest computer modeling software and developing insight into the complex dynamic behavior of structures.

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 practicing engineers, designers, structural engineering students with state-of-the-art information about the latest structural design philosophies.

The performance-based design (PBD) approach is a recent shift in our understanding of structural design. It provides a systematic and flexible methodology for assessing the structural performance of a building, system or any component, as opposed to the cookbook type design methods prescribed in building codes. This methodology explicitly evaluates the response of the buildings under the potential seismic hazard while considering different probable site-specific seismic demand levels (Service Level Earthquake (SLE) and Maximum Considered Earthquake (MCE)). For this purpose, various state-of-the-art nonlinear analysis procedures and latest computer modeling tools are used to accurately determine the seismic demands of whole structure and its individual components.

This course aims to develop basic expertise and skill among UG students about various practical aspects of seismic design of buildings and structures.

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.

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
  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

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

3) An Introduction to Building Code of Pakistan (BCP) 2022 – Shifting from UBC 1997 to IBC 2021: Implications and Challenges

4) Capacity Design and Ductility Design of Structures

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

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]
  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)

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

8) Performance Evaluation of Individual RC Components
   - RC Beams and Columns
   - RC Shear Walls
   - RC Foundations
   - RC Diaphragms

9) Structural Performance and Cost Optimization

10) Presentation of Results of Performance-based Seismic Evaluation

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

Textbooks

- 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, NY, 2nd Ed.
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.

International Standards/Guidelines

1) TBI (2017): 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 41-17 (2017): 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)

Research Journals:

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

Internet Resources

Useful Websites

- 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

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

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/

Video Playlists

1) 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: https://www.youtube.com/watch?v=YZD1jsOfCrs

2) 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

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

   ETABS:
   https://www.youtube.com/playlist?list=PLvfsqlqjBW58i-IZCMASzoAVRT05sKqqo

   PERFORM 3D:
   https://www.youtube.com/playlist?list=PL724CE0F99234D56A

4) 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)

   Day 1 (Training on Other CSI Software):
   Link: https://www.youtube.com/playlist?list=PLYeAciYEtcX3kwpGSMWEtQoepHK9zx6di

   Day 2 (Training on PERFORM 3D):
   Link: https://www.youtube.com/playlist?list=PLYeAciYEtcX2xYSZaymn1mEndagjf-suD

5) Lecture Series on Performance Based Design: State of Practice for Tall Buildings
   Description: A full playlist (presentations) from the 2014 Earthquake Engineering Research Institute (EERI) Technical Seminar Series – "Performance Based Design: State of Practice for Tall Buildings".
   Link: https://www.youtube.com/playlist?list=PLgb4NAA-TyU2qGUmtabhMQlMj5riquPVv

6) Talk and Group Panel Discussion on Performance-based Design
   Description: Special Talk on PBD by Mr. Ron Klemencic at the Asian Institute of Technology (AIT), Thailand, November 2017.
   Link: https://www.youtube.com/playlist?list=PLYeAciYEtcX1E5ranJgvxHQNw9gZio3OU

7) Ashraf Habibullah Talks
   Description: CSI founder and CEO Ashraf Habibullah talks during a one-day seminar titled "The theory and practice of Performance-Based Design: The Future of Earthquake Engineering."

   Links:
   i. The 4 performance levels in PBD
      https://www.youtube.com/watch?v=SgX5SvSqVDA

   ii. Nonlinear analysis and energy dissipation
      https://www.youtube.com/watch?v=Ezi4e9Xscic

   iii. Animations in structural engineering
      https://www.youtube.com/watch?v=SGa1wzZEUsQ

   iv. Strength and deformation of tall structures
      https://www.youtube.com/watch?v=wNDcg93j8w4

v. The Advantage of a Ritz Analysis over an Eigen Analysis in Dynamics
https://www.youtube.com/watch?v=E12x8nulJiI

vi. The Power of Virtual Work in Deflection Control of Structures
https://www.youtube.com/watch?v=LkyBlEuCrBE

vii. Optimization in Design of Large Steel Structures
https://www.youtube.com/watch?v=S_AkjQc9gaQ

8) IRIS Earthquake Science (Youtube Channel)
Description: Official YouTube channel of Incorporated Research Institutions for Seismology
Link: https://www.youtube.com/user/IRISEnO

Term Project

The Performance-based Seismic Evaluation of a Real Case Study Building.

Grading Scheme

Assignments + Quizzes	20%
OHT Exams	30%
Term Project	10%
End Semester Exam	50%
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)
H-12 Islamabad, Pakistan
Cell: 92-334-5192533, Email: fawad@nice.nust.edu.pk
Office No: 118, 1st Floor, NIT Building, SCEE, NUST

Tentative Lecture Plan (Spring 2022)

Week No.	Date (approx.)	Class Topics	Duration (approx.)
1	Session 1	Course Introduction	1.5 Hours
	Session 2	Basics of Seismology	1.5 Hours
2	Session 1	Introduction to Seismic Hazard Analysis	1.5 Hours
	Session 2	Introduction to Seismic Hazard Analysis	1.5 Hours
3	Session 1	Introduction to Seismic Hazard Analysis	1.5 Hours
	Session 2	Concepts of Spectral Acceleration and Response Spectrum, Site-specific Response Spectrum, Design Spectrum in Building Codes	1.5 Hours
4	Session 1	A Step-by-step IBC Approach to the Seismic Analysis and Design	1.5 Hours
	Session 2	A Quick Review of all Seismic Analysis Procedures	1.5 Hours
5	Session 1	An Introduction to Building Code of Pakistan (BCP) 2022 – Shifting from UBC 1997 to IBC 2021: Implications and Challenges	1.5 Hours
	Session 2	Capacity Design and Ductility Design of Structures	1.5 Hours
6	Session 1	Capacity Design and Ductility Design of Structures	1.5 Hours
	Session 2	Introduction to Performance-based Design Approach, PBD Basics and Methodology, Structural Performance Levels and Acceptance Criteria	1.5 Hours

7	Session 1	Introduction to Performance-based Design Approach, PBD Basics and Methodology, Structural Performance Levels and Acceptance Criteria	1.5 Hours
	Session 2	Tall Buildings Initiative (TBI) Guidelines for Performance-Based Seismic Design of Tall Buildings (2017)	1.5 Hours
8	Session 1	Ground Motion Characterization in Performance-based Design	1.5 Hours
	Session 2	Basic Considerations in Modeling and Analysis	1.5 Hours
9	Session 1	Service-Level Earthquake (SLE) Evaluation	1.5 Hours
	Session 2	Maximum Considered Earthquake (MCER) Evaluation	1.5 Hours
10	Session 1	Fundamentals of Nonlinear Modeling – Distributed and Lumped Plasticity Approaches – Hysteretic Behaviors, Strength Loss, Cyclic Degradation	1.5 Hours
	Session 2	Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)	1.5 Hours
11	Session 1	Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)	1.5 Hours
	Session 2	Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)	1.5 Hours
12	Session 1	Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)	1.5 Hours
	Session 2	Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)	1.5 Hours
13	Session 1	Nonlinear Dynamic Analysis of Buildings for MCER Evaluation	1.5 Hours
	Session 2	Hands-on Training Session on “PERFORM 3D” (Nonlinear Modeling of various Structural Components)	1.5 Hours
14	Session 1	Interpreting the Dynamic Response and Seismic Performance of Buildings, Understanding the Analysis Results from Nonlinear Time History Analysis	1.5 Hours

	Session 2	Performance Evaluation of Individual RC Components (RC Beams and Columns)	1.5 Hours
15	Session 1	Performance Evaluation of Individual RC Components (RC Shear Walls)	1.5 Hours
	Session 2	Performance Evaluation of RC Foundations and Diaphragms	1.5 Hours
16	Session 1	Structural Performance and Cost Optimization	1.5 Hours
	Session 2	Presentation of Results of Performance-based Seismic Evaluation	1.5 Hours