CIVL7008 Seismic Analysis for Building Structures

Lec-01 Introduction of Dynamics and Seismic
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Who am I?

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What is Seismic?

Seismic Design → Design the structure to resist earthquake
Seismic Analysis → Estimate the structure safety against to earthquake
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Course Outline

Course code: CIVL7008
Course title: Seismic Analysis for Building Structures
Offered by (department): Department of Civil Engineering
Level: MSc
Credit units: One module
Pre-requisite course code: Nil
Co-requisite course code: Nil
Learning hours: Lecture (30 hours)
Student quota: 100
Course type: Discipline course for MSc(Eng) in Structural Engineering
Offer in academic year: See announcement by Department
Assessment (%): Written examination (60%)
Continuous assessment (40%)
Course Description and Aims

Syllabus: This course aims to provide students with knowledge and understanding in dynamic behaviour and seismic analysis methods for buildings. Students will be exposed to fundamental concepts of structural dynamics; vibration of single-degree-of-freedom systems; vibration of multiple-degree-of-freedom systems; base-shear method; response spectrum analysis; coefficient-based method; estimation of seismic drift demand and capacity.

Upon completion of this course, students who fulfill the requirements of the course will be able to:
1. Understand the dynamics and seismic behaviour of building structures.
2. Understand the vibration of single- and multiple-degree-of-freedom systems.
4. Seismic drift estimation by the coefficient based method.
5. Inelastic estimation of seismic drift capacity

Course Assessment Tasks and Alignment with Learning Outcomes

Assessment tasks in this course are described below, which includes weighting, assessment type, and alignment with course learning outcomes.

Weighting of continuous assessment and written examination

<table>
<thead>
<tr>
<th>Assessment Type</th>
<th>Percentage of Total Assessment (%)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Assessment</td>
<td>40</td>
<td>Assignments.</td>
</tr>
<tr>
<td>Written Examination</td>
<td>60</td>
<td>2-hour written examination.</td>
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</tbody>
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Course Content

- Lec 01 Introduction of seismic and dynamics
- Lec 02 Free/Harmonic Vibration of SDOF
- Lec 03 Force Vibration of SDOF
- Lec 04 Modal Analysis of MDOF
- Lec 05 Vibration Calculation of MDOF
- Lec 06 Response Spectrum Analysis Method
- Lec 07 Seismic Analysis for Building (Prof Su)
- Lec 08 Seismic Design for Building Stru. (Dino)
- Lec 09 Seismic Analysis for Building (Prof Su)
- Lec 10 Seismic Nonlinear analysis method
- Lec 11 introduction of seismic software
- Lec 12 Explanation of Assignment

SDOF SYSTEM

- Assignment 1

MDOF SYSTEM

- Assignment 2

DESIGN / ANALYSIS

- Assignment 3
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Learning Resource

- Ray Clough, Dynamics of Structures.
- Roy R. Craig, Jr. Structural Dynamics
- Frankling Y Cheng. Matrix Analysis of Structural Dynamics
- M. Daniel Vanderbit, Matrix Structural Analysis
- Paulay T and Priestley MJN. Seismic Design of Rein. Conc. and Masonry Buildings
Seismic hazard map

The majority of major earthquakes occur beneath the earth's surface around fault lines, the places where tectonic plates meet. Under pressure, the plates shift suddenly which causes rock to crack and movements in the earth's crust. The stored energy is released in the form of seismic waves of varying strength.

Maximum soil acceleration (m/s²), which occurs in the area on average once every 500 years (10% probability of a quake like this within the next 50 years).

Source: Global Seismic Hazard Program

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[1]Earthquake In Japan M 5.1
Earthquake and building collapse

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Shaking Table Test

[3] [4]E-Defense 6 Story Shake Table.mp4
Dynamics and Static

Static and Dynamic

Static Load → Structural System → Static Response → Static Load

Magnitude Direction Location

Static Load

100kN

Static Load

Magnitude Direction Location

Dynamic Load → Dynamic Structural System → Dynamic Response → Dynamic Load

Magnitude Direction Location

Dynamic Load

100kN

Dynamic Structural System

Stiffness, K Mass, M Damping, C

Dynamic Structural System

Stiffness, K Mass, M Damping, C

SOF System

F

u

disp

Dynamic Response

Displacement u Velocity \dot{u} Acceleration \ddot{u}

Internal Force, N, M

Stress and Strain, \varepsilon, \sigma

SOF System

F(t)

K

M

u

disp

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Dynamic Loading

Typical Dynamic Load For Structures

- Harmonic Loading
- Blast Loading
- Unbalanced Rotating Machine in building
- Human-induced Vibration
- Earthquake "Load"
- Ground Acceleration
- Earthquake Center
- Wind Vibration
- High-rise building
- Wind force time-history
Dynamic Loading

[5] Human induced vibration

Harmonic Loading

Human-induced Vibration

P(t)

[6] wind induced vibration

Wind Vibration

High-rise building

Wind Force

P(t)

Wind force time-history

Time
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Dynamic, Concept and Terms

How to simulate dynamic system

Continuous system

Multiple degree of freedom MDOF

MDOF system

Finite element Model System

Building Structure

MDOF System

Dynamic System

Ground Acceleration
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SDOF System

- **Stiffness, \( K \)**: Stiffness Spring Force, Elastic Resistance to displacement
- **Damping, \( C \)**: Damping, Energy Loss Mechanism
- **Mass, \( M \)**: Mass, Inertia Force

**Dynamic Loading** \( P(t) \)

**SDOF System**

**Undamped system**

**Damped System**
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Basic: Equation of Motion

Dynamic System

Damped System

Equation of Motion

\[ F_p = P(t) = F_i + F_d + F_s \]

\[ m \ddot{u} + c \dot{u} + ku = p(t) \]

[7] SDOF Resonance Vibration Test
Feature of this course

- Blackboard Writing (easy understand)
- Calculation Example (hand Calculation)
- Interesting Animation
- Learning Programing (how to make program)
- Learning Engineer’s Software
  (ETABS/SAP2000/OPENSEES)
- the examination
- Assignment (3 Assignments)
- Engineer’s Experience (introduction)
- Free Discussion (10~20 min)
Seismic Design: Super high-rise building based on Chinese Code

380m SZ Gangxia Center Tower (Seismic Structural System)
Seismic Design: Super high-rise building based on Chinese Code

High-rise building modal analysis, mode shape
Seismic Design: Super high-rise building based on Chinese Code

Ground motion and story drift curve under frequent earthquake “load”

GM1

GM2

GM3

Story Drift (Response) of Structure under earthquake “Load”

Story Drift in X Direction

Story Drift in Y Direction

Spectrum
Dynamic: wind time-history Analysis

Program Make Wind Time History

Wind tunnel monitor point map
Dynamic: wind time-history Analysis

Time History Data from wind tunnel

(Story Force) Time History Data from wind tunnel
Viscous Dampers are used to control the earthquake vibration, protect the people and medical facilities.
Seismic Design: Structural Damper Study

Figure 4. K-Brace-Damper System
Connected Structure Seismic Design

120m long-span steel truss top gallery
10.5m wide, 9.5m high steel truss structure with viscous dampers
86.5m high right tower
Reinforced concrete frame-shear wall structure with viscous dampers
86.5m high left tower
Reinforced concrete frame-shear wall structure with viscous dampers
Steel structure bottom gallery

Mega Gate Structure

Figure 7. Load coefficient-top displacement curve of the left tower
Mega Gate Structure,
Construction of long span truss
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Connected Structure Seismic Design
Connected Structure Seismic Design

Shake Table Model Test
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Wind Tunnel Test For Connected Tower

Wind induced vibration checking
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Nonlinear Analysis (Blind Analysis Contest)

BLIND ANALYSIS CONTEST 2007

2007 Blind Analysis

"Collapse Test of a Full-scale Four-story Steel Building"

Blind analysis contest of Full-scale test using E-Defense shaking table will be executed. Participation in the contest can be by either individual or group! Don’t hesitate to apply to the contest to make the closest prediction to the actual test result.

You can join by commercially available software packages.

For details, see

Third Place Award

This is to certify that
Chen Xuewei
Peng Qiaobin
are the Third Place Winners of the 2007 E-Defense Blind Analysis Contest in the category of 3-Dimensional Analysis by Researchers

August 12, 2008

National Research Institute for Earth Science and Disaster Prevention,
Hyogo Earthquake Engineering Research Center

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Nonlinear Analysis (Blind Analysis Contest)

Framing Plan and Elevation of the Specimen

Component Experiment Analyze
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Nonlinear Analysis (Blind Analysis Contest)

Linear Analysis Comparison of OpenSees and SAP2000
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Nonlinear Analysis (Blind Analysis Contest)

Comparison of Results Form Experiment and OpenSEES

Time-History of Drift Angle in Story 1

Photo Shot of Collapse

Deformation of Collapse in OpenSees Post Program (Delphi)
Nonlinear Analysis (Blind Analysis Contest)

E-Defense (shake table test) Full Scale 4 Story Steel Frame
Modal Analysis and mode shape

Mode 59 - Period 0.01466
Mode 62 - Period 0.01365
Mode 68 - Period 0.01241
Mode 84 - Period 0.01003
Mode 85 - Period 0.00980
Mode 93 - Period 0.00817
Modal Analysis and mode shape

Interesting video of Mode Shape
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Open Source Program

What is Lazarus?
Lazarus is a Delphi compatible cross-platform IDE for Rapid Application Development. It has a variety of components ready for use and a graphical form designer to easily create complex graphical user interfaces.

What can it do?
You can create your own open source or commercial applications. With Lazarus you can create file browsers, image viewers, database applications, graphics editing software, games, 3D software, medical analysis software or any other type of software.

Where to learn?
Lazarus has a huge community of people supporting each other. It includes scientists and students, pupils and teachers, professionals and hobbyists. Our wiki provides tutorials, documentations, and ideas. Our forums and mailing-list offer a space to ask questions and talk to users and the developers.

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See Application Gallery  Why use it?

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Open Source Program

SDOF Free Vibration

SDOF Harmonic Vibration

SDOF Duhamel Integration

Modal Analysis (MDOF)
Introduction of Dynamics and Seismic Computation Program (ETABS / SAP2000)

ETABS

- Build Finite Element Model
- Static Analysis
- Modal Analysis
- Spectrum Analysis
- Time History Analysis
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Seismic Tech for Super High Rise Building