

Structural analysis up to collapse under extreme loads: Discrete Element modelling

Instructors:

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PhD Program: Earthquake Engineering (IUSS Pavia)

Term: Academic Year 2026-27

Delivery mode: The course is delivered through standard frontal classes.

Where: Palazzo del Broletto, IUSS Pavia, piazza della Vittoria 15, Pavia, Italy

Class duration: 10th December – 18th December 2026 (24 hours)

Office hours: Contact the instructors via e-mail.

Course description

This doctoral-level course introduces discrete element modelling approaches for structural analysis under both ordinary and exceptional loads (e.g. seismic action). It introduces common discrete element (DE) approaches, e.g. the Distinct Element Method (DEM) and Applied Element Method (AEM), for analyzing structures from the very initial elastic response up to the collapse and the derivation of debris pattern, highlighting pros and cons against continuum-based techniques, namely the widely adopted Finite Element Modelling (FEM). It addresses the need for advanced modeling techniques in structural engineering, covering the basics of discrete methods, governing principles, numerical methods, and modeling of masonry, steel, and reinforced concrete structures. It combines theoretical lectures with practical tutorials using advanced discrete-based computational software. Real applications, including collapsed and earthquake-damaged structures, will be also presented. Students will learn to model, analyze, and interpret the behavior of structures using AEM-based tools.

Learning Outcomes

Upon completion of the course, the student is expected to be able to:

- recognize and understand the importance of fracture in solids in various contexts such as structural engineering and failure analysis,
- observe, interpret and describe the mechanical behavior of systems composed of rigid body elements; and
- use the of Applied Element Method-based platforms as a tool for structural response analysis of simple structures up to collapse.

Course requirements

Knowledge of structural engineering and Finite Element modelling.

Course notes and references

Slide sets and bibliography posted on Google Drive.

Assessment

One assignment will be given and graded during the course. It involves modeling and analyzing simple structural systems under various loading conditions, as well as addressing a real-world structure under earthquake loading up to collapse.

Course schedule

Date	Time	Class room	Subject	Hours
10/12/2026	10.00 am to 1.00 pm	1-17	Lecture 1: <ul style="list-style-type: none"> <i>Part 1:</i> Course overview and Discrete Approaches: History, applications, and significance. (NS) <i>Part 2:</i> Fundamentals of Discrete Element Modelling. (MC) 	2h 1h
	2.00 pm to 5.00 pm	1-17	Lecture 2: Governing Principles and Numerical Methods of the Applied Element Method (AEM). (MC) Tutorial 1: Introduction to the AEM platform <i>Extreme Loading for Structures</i> (ELS). (MC)	2h 1h
11/12/2026	10.00 am to 1.00 pm	1-16	Lecture 3: <ul style="list-style-type: none"> <i>Part 1:</i> AEM modeling of Mechanical Behavior of Continuous and Brittle Materials. (MC) <i>Part 2:</i> From elastic to nonlinear material behavior within the AEM framework. (MC) 	2h 1h
	2.00 pm to 4.00 pm	1-16	Tutorial 2: Q&A, <u>Assignment</u> . AEM linear and nonlinear modelling: define/calibrate the relevant parameters. (MC)	2h
14/12/2026	10.00 am to 1.00 pm	1-16	Lecture 4: <ul style="list-style-type: none"> <i>Part 1:</i> AEM & DEM modelling and analysis up to collapse of structures. (NS) <i>Part 2:</i> Applications in forensic engineering. (NS) 	2h 1h
	2.00 pm to 5.00 pm	1-16	Tutorial 3: AEM nonlinear static and dynamic analysis up to collapse, Q&A. (NS)	3h
16/12/2026	9.00 am to 1.00 pm	1-16	Tutorial 5: Introduction to an alternative AEM platform <i>OMNIA</i> . (GG)	4h
	2.00 pm to 4.00 pm	1-16	Tutorial 4: Q&A. (NS, MC, GG)	2h
17/12/2026	9.00 am to 10.00 am	1-15	Tutorial 6: Q&A. (NS, MC, GG)	1h
TOTAL HOURS (LECTURES + TUTORIALS)				24
18/12/2026	10.00 am to 1.00 pm	1-15	Exam: Assignment presentation and discussion.	3h