Introduction to Discrete Element Approaches for Structural Analysis

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PhD Program: Earthquake Engineering (IUSS Pavia)
Term: Academic Year 2024-25
Delivery mode: The course is delivered through standard frontal classes.
Where: Palazzo del Broletto, IUSS Pavia, piazza della Vittoria 15, Pavia, Italy
Class duration: 13th January – 23rd January 2025 (30 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 discrete modelling (e.g. 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
Basic knowledge of structural modelling 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.

Course schedule

Date	Time	Class room	Subject	Hours
13/01/2025	10.00 am to 1.00 pm	Aula 1-15, IUSS	**Lecture 1** • *Part 1:* Course overview and Discrete Approaches: History, applications, and significance. (NS) • *Part 2:* Fundamentals of Discrete Element Modelling. (MC)	2h 1h
	2.00 pm to 5.00 pm	Aula 1-15, IUSS	**Lecture 2**: Governing Principles and Numerical Methods of the Applied Element Method (AEM). (MC)	3h
14/01/2025	9.00 am to 12.00 pm	Aula 1-15, IUSS	**Lecture 3**: AEM modeling of Mechanical Behavior of Continuous and Brittle Materials. (MC)	3h
	2.00 pm to 4.30 pm	Aula 1-15, IUSS	**Tutorial 1**: Introduction to the AEM platform *Extreme Loading for Structures* (ELS) and linear elastic analysis, Q&A, Assignment. (MC)	2.5h
15/01/2025	9.00 am to 12.00 pm	Aula 1-15, IUSS	**Lecture 4**: AEM and DEM modelling of Structural Components: a comparison with Finite Element modelling. (NS)	3h
	2.00 pm to 6.00 pm	Aula 1-15, IUSS	**Tutorial 2**: Introduction to the AEM platform *OMNIA* and testing linear and nonlinear constitutive behavior. (GG)	4h
21/01/2025	9.00 am to 12.00 pm	Aula 1-15, IUSS	**Lecture 5** • *Part 1:* Advanced Applications and Complex Structures; Real applications to collapse analysis. (NS) • *Part 2:* Future perspectives for AEM modelling. (MC)	3h 1h
	2.00 pm to 4.30 pm	Aula 1-15, IUSS	**Tutorial 3**: Nonlinear static and dynamic analysis, and debris estimation using ELS, Q&A. (NS)	2.5h
22/01/2025	2.00 pm to 4.00 pm	Aula 1-15, IUSS	**Tutorial 4:** Q&A. (NS, MC, GG)	2h
23/01/2025	3.00 pm to 6.00 pm	Aula 1-15, IUSS	**Exam:** Assignment presentation and discussion.	3h
			TOTAL HOURS	**30**