

INTEGRATED ASSESSMENT AND RETROFITTING OF EXISTING BUILDINGS

FIRST SEMESTER 2022-2023

Instructors: Rui Pinho, Ricardo Monteiro, Giammaria Gabbianelli, Martina Caruso, Francesco Cavalieri, Gianrocco Mucedero

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Teaching Assistant: Rita Couto (rita.couto@iusspavia.it)

CLASS SCHEDULE

November 15 to December 14, 2022, Broletto, IUSS, Pavia, Italy

Lectures/Tutorials: Tuesdays, Wednesdays, and Thursdays

OFFICE HOURS

Contact the instructors or the teaching assistant to schedule an appointment

BACKGROUND

Basic knowledge of seismic hazard, seismic analysis, and loss assessment of existing RC buildings. Any requirement for energy and environmental assessment procedures.

GENERAL OBJECTIVES

The main objective of the course is to provide an overview of state-of-art methodologies for the integrated seismic/energy assessment and retrofitting of existing buildings, which are of primary importance in the current climate change emergency. The shift to a multi-disciplinary and holistic perspective in the design approach is indeed necessary. The course will provide the state-of-art methodologies for seismic fragility analysis, seismic risk assessment, and seismic retrofitting, as well as for energy performance assessment and retrofitting, environmental impact evaluation, and decision-making.

COURSE NOTES AND REFERENCES

Slide sets and bibliography posted on Google Drive

LECTURES

Lecture 1

INTRODUCTION (1.5 h) – Ricardo Monteiro/Rui Pinho

- General overview of the course (topics, tutorials, project);
- European targets and objectives: Paris Agreement, European Green Deal, New Bauhaus, Next Generation EU, Sustainable Development Goals;
- Definition of a new concept of sustainability (environment, economy, and society), including structural/seismic safety;
- Existing R.C. buildings: main structural and energy issues and deficiencies, common uncoupled/sectorial approach to their assessment and retrofitting;
- Introduction to the integrated (multi-performance) assessment and retrofitting of buildings.

SEISMIC ANALYSIS AND PERFORMANCE OF EXISTING R.C. STRUCTURES (1.5 h) - Rui Pinho

- Modelling issues for existing R.C. structures;
- Knowledge levels for existing R.C. buildings;
- Nonlinear behaviour of R.C. structures.

Tutorial 1: Use of SeismoStruct – Rita Couto

Lecture 2

SEISMIC ANALYSIS AND PERFORMANCE OF EXISTING R.C. STRUCTURES (3h) – Ricardo Monteiro

- Methods of analysis;
- Overview of seismic assessment procedures.

Tutorial 2: Use of SeismoStruct – Rita Couto

Lecture 3

SEISMIC FRAGILITY ANALYSIS (4h) – Francesco Cavalieri

- Basics of probability theory;
- Seismic hazard;
- Seismic fragility analysis;
 - IM-based methods (Cloud, IDA, MSA);
 - Record selection methods and tools;
 - Definition of fragility function (or fragility curve);
 - Derivation of fragility using static pushover results;
 - Derivation of fragility using IM-based method results.

Tutorial 3: Record selection (using SeismoSelect and EzGM) for a given site; derivation of the collapse fragility curve for the case study building using all three IM-based methods – Rita Couto/Francesco Cavalieri

Lecture 4

SEISMIC RETROFITTING STRATEGIES FOR R.C. STRUCTURES (4h) – Gianrocco Mucedero

- Overview of typical deficiencies in R.C. buildings, review of relevant terminology, goals of retrofit strategy;
- Selective intervention techniques: stiffness, strength, ductility;
- Structural-level approach of retrofitting:
 - Conventional Methods: R.C. walls; Steel Bracing or Infill Walls into/onto the Existing Frame;
 - Non-Conventional Methods: base isolation, viscous dampers;
- Member level approach or local retrofitting: jacketing, metallic haunch, FRP, steel plate, others.

Tutorial 4: Design of seismic retrofitting strategies and implementation in SeismoStruct – Rita Couto/Gianrocco Mucedero

Lecture 5

SEISMIC LOSS ASSESSMENT (3h) – Gianrocco Mucedero

- PEER loss estimation framework and brief introduction to PACT: description of the fully probabilistic framework, component fragilities and consequence functions, advantages/limitations;
- Story-loss functions: framework, EDP-DV functions, building components and cost distributions, SLF estimation toolbox, advantages/limitations;
- Simplified approaches: DBLA, SismaBonus.

Tutorial 5: Use of PACT for seismic loss assessment of pre- and post-intervention configurations - Rita Couto/Gianrocco Mucedero

Lecture 6

ENERGY PERFORMANCE ASSESSMENT (3h) – Francesco Cavalieri

- Energy use in buildings, operational energy, primary/secondary energy, CO₂ emissions;
- Annual heating/cooling demand in European buildings;
- Energy classification of buildings;
- Definition of heating degree days (HDD) and cooling degree days (CDD);
- Mechanisms of heat transfer;
- Energy balance of a building;
- Different regimes of analyses: stationary (seasonal), semi-stationary state (monthly), dynamic (hourly);
- Data needs about the building and the site where it is located:
 - Wall stratigraphy, thermal transmittance, thermo-hygrometric conditions, thermal bridges;
 - Climatic data;
- Solar shading and heating/cooling systems in a building.

Tutorial 6: Introduction to Edilclima – Rita Couto/Martina Caruso

Lecture 7

ENERGY EFFICIENCY RETROFITTING STRATEGIES FOR R.C. STRUCTURES (3h) – Martina Caruso

- Main challenges of energy efficiency retrofitting;
- Traditional and innovative energy retrofitting solutions (thermal coatings, replacement of windows, photovoltaics, thermal insulation, replacement of existing heating, cooling, and lighting systems, etc).

Tutorial 7: Design of energy retrofitting strategies and implementation in Edilclima – Rita Couto/Martina Caruso

Lecture 8

DECISION-MAKING APPROACHES FOR THE TRADITIONALLY UNCOUPLED ASSESSMENT AND OPTIMAL RETROFITTING OF BUILDINGS (3h) – Giammaria Gabbianelli

- Traditional uncoupled (seismic or energy) decision-making approaches: expected annual loss, seismic resilience-based assessment, index-based method, seismic risk classification, incremental seismic rehabilitation, energy classification, cost-benefit analysis, life cycle assessment, green resilience indicator.

Tutorial 8: Application of one of those approaches – Rita Couto/Giammaria Gabbianelli

Lecture 9

INTEGRATED ASSESSMENT AND RETROFITTING OF BUILDINGS (1h) – Martina Caruso

- Life Cycle Structural Engineering (LCSE) approach;
- Sustainability parameters;
- Life Cycle Thinking (LCT) performance objectives.

ENVIRONMENTAL IMPACT ASSESSMENT (2h) – Martina Caruso

- Life Cycle Assessment (LCA): contents, boundaries, types;
- Legislation/standards, available tools and databases;
- Life Cycle Cost Assessment (LCCA) and Social Life Cycle Assessment (S-LCA) procedures;
- Environmental impact assessment and seismic loss estimation: damage-to-impact conversion methods.

INTEGRATED RETROFITTING STRATEGIES (1h) – Martina Caruso/Giammaria Gabbianelli

- Examples of coupled/integrated retrofitting techniques: incremental strategies for coupled/integrated retrofitting, seismic thermal coating, textile reinforced mortar (TRM) jacketing coupled with a thermal insulation layer, exoskeletons, etc.;
- Examples of new buildings designed based on an integrated strategy (lightweight structures, etc), EPS, mixed wood-R.C. (XLAM).

Tutorial 9: Calculation of environmental impacts due to seismic risk and to energy consumption – Rita Couto/Martina Caruso/Giammaria Gabbianelli

Lecture 10

DECISION-MAKING TOOLS FOR THE INTEGRATED ASSESSMENT AND OPTIMAL RETROFITTING OF BUILDINGS (4h) – Martina Caruso/Giammaria Gabbianelli/Francesco Cavalieri

- Global decision-making parameters: Menna, Lamperti Tornaghi, etc.;
- Multi-criteria Decision-Making approaches: Clemett et al., Caruso et al., etc.;
- Analysis of critical infrastructure (including lifelines) for a more accurate estimation of downtime.

Tutorial 10: Application of one of those approaches – Rita Couto/Martina Caruso/Giammaria Gabbianelli

ASSIGNMENTS

The assignments must be solved in groups. The same teams must be maintained during the entire course. Each assignment shall be neatly written and shall be handed in on time. The first page of each assignment shall include the course name (i.e. Integrated Assessment and Retrofitting of Existing Buildings), the title of the assignment, the date, the student name(s) and signature(s). Each assignment will be returned a maximum of one week after the due date.

GRADING

Evaluation	% of Final Mark	Documentation
Assignments	50%	PDF
Project presentation	50%	PowerPoint + PDF

COURSE SCHEDULE

Week	Date	Lecture hours	Tutorial hours	Subject	Total
1	15/11/2022	10.00 am to 1.00 pm Aula 1-17, IUSS	2.30 pm to 4.30 pm Aula 1-17, IUSS	Lecture 1: Introduction + Seismic analysis and performance of existing R.C. structures Tutorial 1: Use of SeismoStruct, Q&A, Assignment No. 1.	5
	16/11/2022	10.00 am to 1.00 pm Aula 1-17, IUSS	2.30 pm to 4.30 pm Sala del Camino, IUSS	Lecture 2: Seismic analysis and performance of existing R.C. structures Tutorial 2: Use of SeismoStruct, Q&A.	5
	17/11/2022	9.00 am to 1.00 pm Sala del Camino, IUSS	2.30 pm to 4.30 pm Sala del Camino, IUSS	Lecture 3: Seismic fragility analysis Tutorial 3: Record selection, Q&A.	6
2	22/11/2022	9.00 am to 1.00 pm Sala del Camino, IUSS	2.30 pm to 4.30 pm Sala del Camino, IUSS	Lecture 4: Seismic retrofitting strategies for R.C. structures Tutorial 4: Design of seismic retrofitting strategies, Q&A, Assignment No. 1 due at 4.30 pm, Assignment No. 2.	6
	23/11/2022	10.00 am to 1.00 pm Aula 1-17, IUSS	2.30 pm to 4.30 pm Sala del Camino, IUSS	Lecture 5: Seismic loss assessment Tutorial 5: Use of PACT, Q&A.	5
	24/11/2022	10.00 am to 1.00 pm Sala del Camino, IUSS	2.30 pm to 4.30 pm Sala del Camino, IUSS	Lecture 6: Energy performance assessment Tutorial 6: Introduction to Edilclima, Q&A.	5
3	29/11/2022	10.00 am to 1.00 pm Aula 1-17, IUSS	2.30 pm to 4.30 pm Aula 1-17, IUSS	Lecture 7: Energy efficiency retrofitting strategies for R.C. structures Tutorial 7: Design of energy retrofitting strategies, Q&A, Assignment No. 2 due at 4.30 pm, Assignment No. 3.	5
	30/11/2022	10.00 am to 1.00 pm Aula 1-17, IUSS	2.30 pm to 4.30 pm Aula 1-17, IUSS	Lecture 8: Decision-making tools for the traditionally uncoupled assessment and optimal retrofitting of buildings Tutorial 8: Application of one of those approaches, Q&A.	5
	01/12/2022	9.00 am to 1.00 pm Sala del Camino, IUSS	2.30 pm to 3.30 pm Sala del Camino, IUSS	Lecture 9: Integrated assessment and retrofitting of buildings + Environmental impact assessment + Integrated retrofitting strategies Tutorial 9: Calculation of environmental impacts, Q&A.	6
4	06/12/2022	9.00 am to 1.00 pm Aula 1-17, IUSS	2.30 pm to 4.30 pm Aula 1-17, IUSS	Lecture 10: Decision-making tools for the integrated assessment and optimal retrofitting of buildings Tutorial 10: Application of one of those tools, Q&A, Review, Assignment No. 3 due at 4.30 pm, Assignment No. 4.	6
				Total hours	54
	14/12/2022 (TBC)	10.00 am to 1.00 pm Aula 1-17, IUSS		Project presentation.	3