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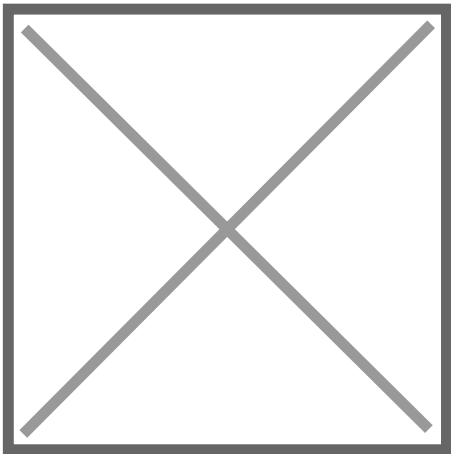
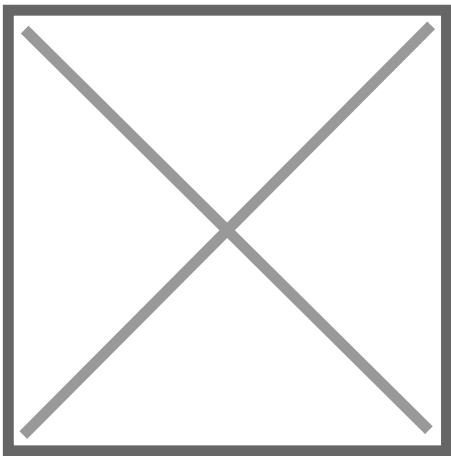
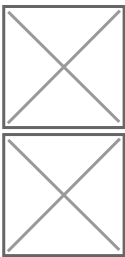
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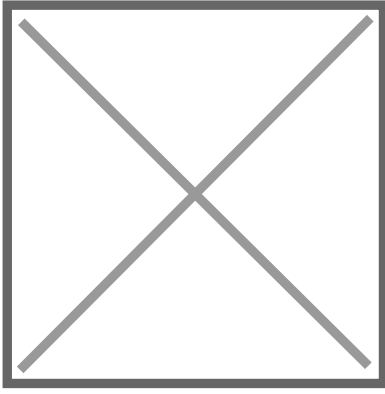
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Add to Compare

M2 Advanced Materials, Structure and Energy for sustainable construction





Master's degree

Specialisations Energy | Civil Engineering

Enrolment type

Full-time academic programmes

Language(s) of instruction

English

The Department Génie Civil and Environment of ENS Paris-Saclay proposes a research-oriented Master program entitled « **Materials, Structures and Energy for Sustainable Construction** ». It comprises two M2 programs:

- Program **Modeling and Computing for Construction Engineering**,
- Program **Materials for Sustainable Construction and Environment**.

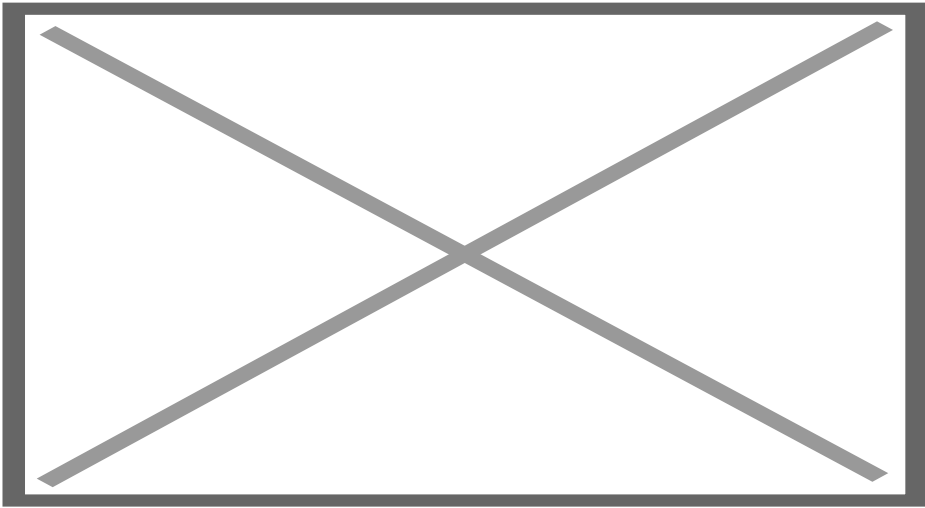
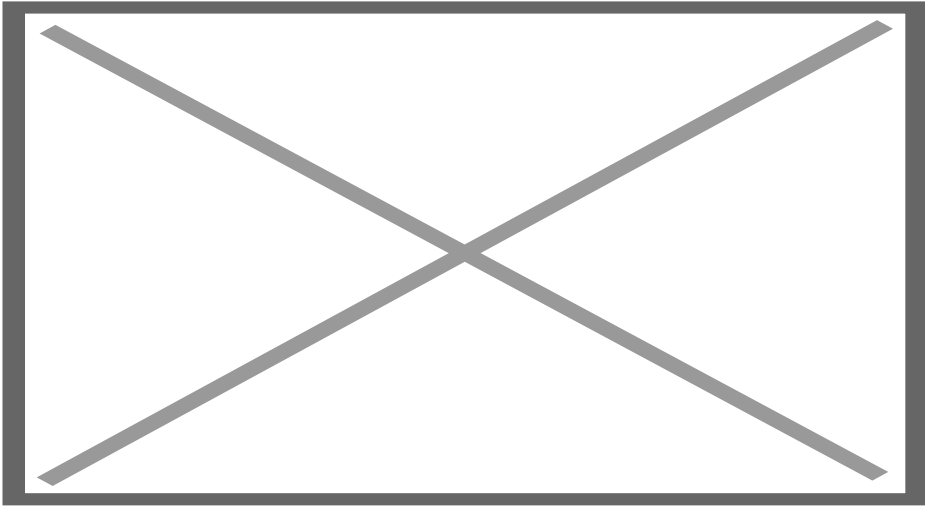
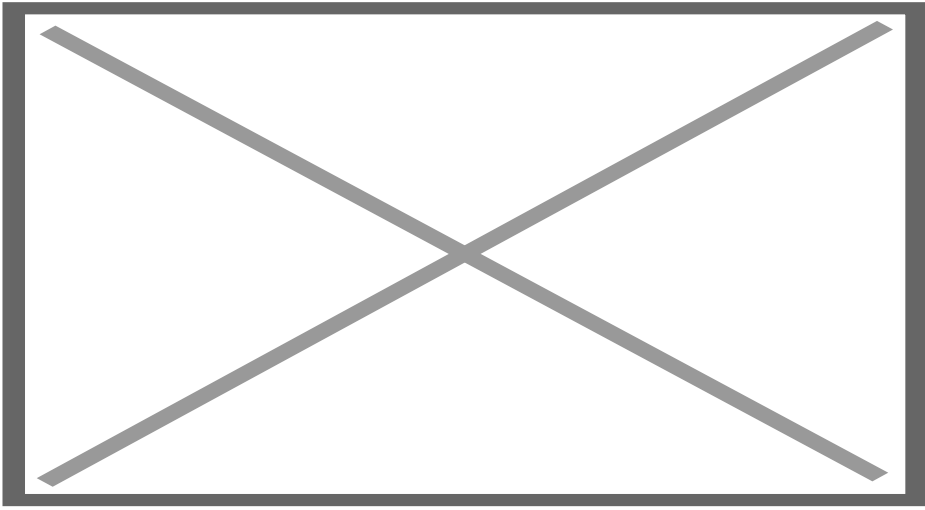
The two M2 programs differ by the mandatory courses of semester S1, and by the research topics of semester S2.

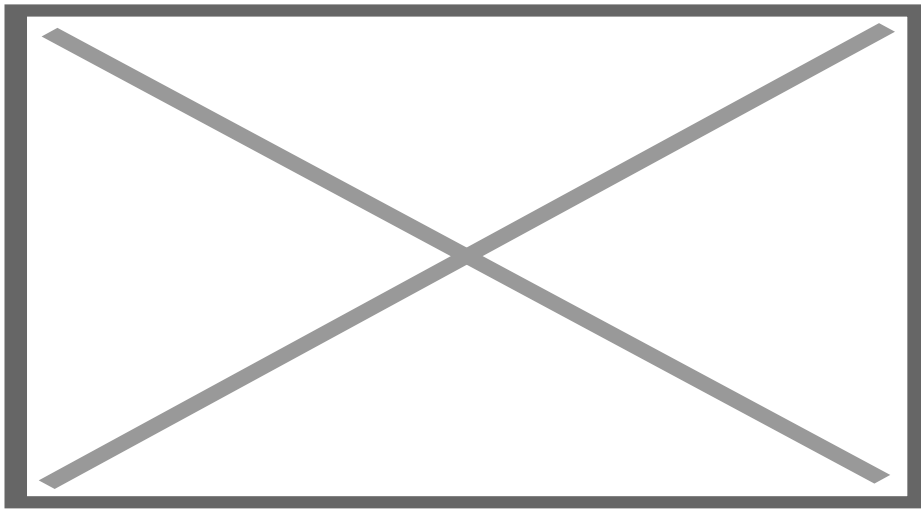
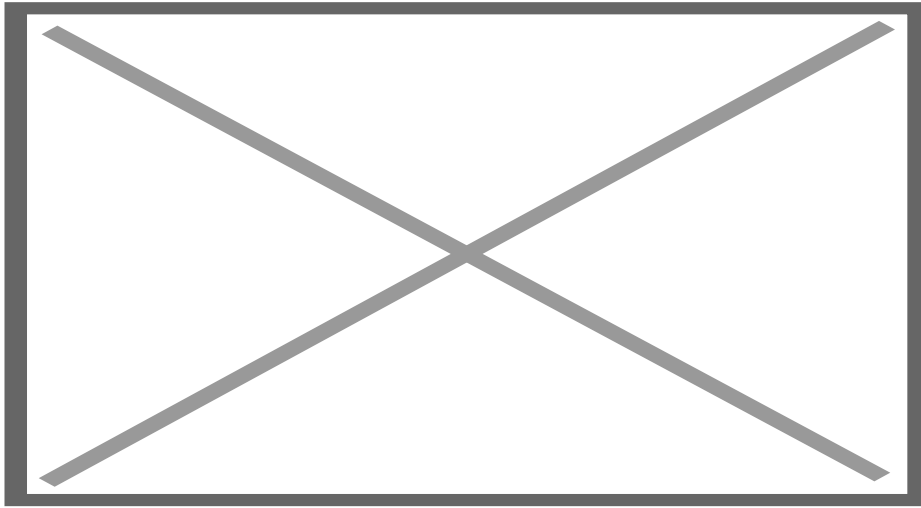
The **Modelling and Computing for Construction Engineering** Master 2 program offers advanced training for future researchers, engineers, and designers in the mechanics of Civil Engineering materials and structures. Particular attention is paid to performance under extreme conditions that exceed standard regulatory requirements. Emphasis is placed on the design and analysis of structures subjected to complex loading, including dynamic, multi-physics, and stochastic (random) effects, as well as damage and failure of both materials and structures.

The **Materials for Sustainable Construction and Environment** Master 2 program is designed to train future researchers, engineers, and designers in developing and characterizing advanced materials for environmentally responsible construction. The program combines theoretical foundations, experimental practice, and research experience to address the challenges of sustainability and performance in construction materials and systems.

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[Apply Now](#)





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Information

- [Overview](#)
- [Application requirements](#)
- [Schedule](#)

Présentation

Skills

For the **Modelling and Computing for Construction Engineering** Master 2 program:

- Advanced experimental investigation for construction engineering (hybrid testing, Digital Image Correlation, etc.).
- Understanding and modeling deformation and degradation mechanisms in materials (durability, porous media, aging, etc.).
- Analysis of damage, rupture, and failure in Civil Engineering materials and structures.
- Mechanics of structures under extreme and non-standard conditions.
- Finite Element computation of non-linear structural responses.

For the **Materials for Sustainable Construction and Environment** Master 2 program:

- Simulate, model, and experiment the behavior (mechanical, thermal, hydric, morphological) of materials and structures in their environment.
- Study advanced materials for sustainable construction and the environment.
- Understand and analyze the degradation and damage mechanisms of these materials, exploring both local and global scales.
- Energy management and sustainable development in construction.
- Propose modern, research-based and high-level courses.

Objectives

For the **Modelling and Computing for Construction Engineering** Master 2 program

- Students develop a solid foundation in scientific methodology, including bibliography analysis, experimental investigation, and the presentation of scientific results. The program develops multidisciplinary skills, combining state-of-the-art experimental tools (e.g., hybrid testing, Digital Image Correlation) with theoretical and numerical modeling. Key points are understanding and simulating non-linear, possibly softening, mechanical behavior of Civil Engineering materials and structures.
- *Program Objectives:*
 - › Bridge the gap between experiments (observations, mechanical responses) and structural modeling for supporting sustainable construction,
 - › Prepare students for research and engineering careers involving high-performance simulation and design under complex mechanical and environmental conditions,
 - › Offer hands-on research experience through a supervised Scientific Training Period in a research lab,
 - › Propose modern, research-based and high-level courses.

For the **Materials for Sustainable Construction and Environment** Master 2 program:

- Students gain a multidisciplinary understanding of material behavior under environmental constraints, exploring mechanical, thermal, hydric, and morphological phenomena. Special focus is placed on the degradation mechanisms, damage, durability, and environmental impact of materials, from microstructural processes to structural performance.
- *Program Objectives:*
 - › Provide a solid theoretical and practical foundation for research-oriented careers in sustainable construction materials.
 - › Cultivate critical thinking and scientific reasoning through applied and investigative learning.
 - › Offer hands-on research experience through a supervised internship in a research lab.

Débouchés

Career prospects

After a Master's + PhD: researcher or lecturer Research and Innovation Manager

Further Study Opportunities

PhD

Postgraduate specialised degree

Calendar

Start of programme (indicative date)

01/09/2026

End of programme (indicative date)

30/09/2027

[Description of the Master program](#)

Admission

Capacity

Available Places

30

Target Audience and Entry Requirements

To enroll in this research-oriented Master 2 program, applicants must have completed at least the first year (M1) of a master degree, with theoretical training in civil engineering.

Engineers seeking to acquire research skills related to the « **Materials, Structures and Energy for Sustainable Construction** » program.

Période(s) de candidature

Inception Platform

From 05/03/2026 to 15/05/2026

Supporting documents

Compulsory supporting documents

Course selection sheet.

Rank of previous year and size of the promotion.

Motivation letter.

All transcripts of the years / semesters validated since the high school diploma at the date of application.

Certificate of English level (compulsory for non-English speakers).

Curriculum Vitae.

Additional supporting documents

VAP file (obligatory for all persons requesting a valuation of the assets to enter the diploma).

[Inception - Selection Form](#)

Programme

Disciplinary Courses

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Digital Image Correlation and Identification (Part I)	1.5	Semestre 1						

Digital Image Correlation and Identification (Part I)

ECTS : 1.5

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Mechanics of Materials, finite-element method, statistics, probability theory

Programme/contents

Lectures on Digital Image Correlation (DIC)

- Imaging devices (photons, electrons, and all the rest, Atomic Force Microscopy, resolution in space and time, 2D/3D, scanning/full field ...)
- Images (grey-level histograms, and encoding depth, color coding, distortions ...)
- Subpixel interpolation (pixel meaning from square box to cardinal splines, all are splines), correlation length, noise
- Optical flow (description of what is conserved in images and what is not). Brightness / Contrast / Temperature / Elevation (Atomic Force Microscopy)
- Kinematic basis (starting from translation and intercorrelation to finite-element)
- Least squares formulation, and numerical solution; 1) gradient descent; 2) multiscale. Discussion on the Hessian matrix (eigenvalue spectrum, eigenmodes)
- Uncertainty quantification, relation with Hessian matrix (motivation for regularization)

Specific challenges and applications of Digital Image Correlation for Civil Engineering structures, mini-structures and specimens

- Examples will illustrate applications of DIC in civil engineering, in particular for the detection and quantification of damage.

Learning objectives

This course is devoted to the introduction of the general principles of Digital Image Correlation (DIC)

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Non-Linear Finite Element Method	3	Semestre 1						

Non-Linear Finite Element Method

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Linear finite-element method, mechanics of materials for non-linear behavior, fundamentals on transfer, fundamentals on numerical methods (numerical integration, interpolation and solving a linear system)

Programme/contents

- Architecture of a finite-element code for non-linear behavior, subroutine for the time integration of constitutive equations
- Computational techniques for the solution of non-linear and time-dependent constitutive equations within the framework of the finite-element method
- Consistent tangent operator
- Explicit and implicit time integration for the evolution equations
- Application to non-linear thermal transfer
- Application to elasto-plasticity
- Application to continuum damage mechanics
- Individual projects for own implementation

Learning objectives

- This course introduces the application of the finite-element method for the numerical prediction of the response of a structure composed of materials with non-linear constitutive behavior. Students learn how to derive systematically the algorithm for any material behavior. The course emphasizes conceptual development for a variety of non-linear constitutive equations. Thermal and mechanical applications are considered. Various temporal schemes are studied to solve evolution equations.

Skills

- By the end of the course, students are able to

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Thermodynamics of Solid Materials (Part I)	1.5	Semestre 1						

Thermodynamics of Solid Materials (Part I)

ECTS : 1.5

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Continuum Mechanics, elasticity, anisotropy, tensor calculus

Programme/contents

The thermodynamics of irreversible processes is presented for solid materials, starting from thermo-poroelasticity up to the framework of standard generalized materials. Associated and non-associated elastoplasticity models are described in a general manner, applicable to both metals and geomaterials.

- Shear/hydrostatic elastic energy density, deviatoric/hydrostatic stress, von Mises stress, anisotropy.
- State variables, poro-elasticity.
- 3D visco-elasticity (elastic energy density, dissipation potential, viscosity larger for shear moduli than for bulk modulus) as a toy model for general constitutive equations.
- Thermodynamics of solid materials: 1st and 2nd principle of thermodynamics, Clausius-Duhem Inequality, intrinsic dissipation.
- Local state method, internal variables (including isotropic and kinematic hardening state variables).
- Infinitesimal strain framework of standard generalized materials (associated / non-associated models), positivity of the intrinsic dissipation, heat equation for local states described by internal variables.
- Associated elasto-plasticity: elasto-plasticity of metallic materials, elasto-plasticity of soils and rocks, poro-elasto-plasticity.

Learning objectives

- The primary objective is to derive, within a thermodynamic framework that incorporates internal variables, the constitutive equations

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Coupled Energy and Mass Transfers in Porous Media	3	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	practical class	directed study/practical class
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Coupled Energy and Mass Transfers in Porous Media

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

- Thermodynamics, heat transfer, and fluid mechanics
- Basic numerical methods
- Fundamentals of materials science or environmental processes

Programme/contents

- Heat and mass transfer in porous and composite materials
- Diffusion, advection, and phase change mechanisms
- Sorption, capillarity, condensation, and chemical coupling
- Governing equations and constitutive relationships
- Multiphase modeling and micro–macro coupling
- Thermodynamic equilibrium and non-equilibrium processes
- Applications: insulation, energy storage, drying, geothermal systems, and remediation

Learning objectives

This course provides an advanced understanding of heat, mass, and momentum transfer in porous and composite materials. It combines theoretical, modeling, and experimental approaches to study phenomena such as diffusion, advection, phase change, and interfacial interactions. The course emphasizes the link between micro- and macro-scale processes and develops advanced skills to model, simulate, and optimize multiphase and multiscale systems using computational tools and sustainability-driven design principles. It enables evaluation of material performance, improvement of energy efficiency, safety, and durability, and supports the development of sustainable technologies and resilient infrastructures in renewable energy, building

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Control of Active and Reactive Systems (Part I)	1.5	Semestre 1						

Control of Active and Reactive Systems (Part I)

ECTS : 1.5

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

- Basic modeling of mechanical and energy systems
- Elementary thermodynamics, heat transfer, or fluid mechanics (recommended)

Programme/contents

- Introduction to controlled energy, mechanical, and transport systems
- Dynamic responses and stability analysis of active and reactive systems
- Principles of feedback and basic optimization
- Coupling of system components under varying boundary conditions
- Case studies: adaptive building systems, active damping, and others
- Research perspectives: design and validation of adaptive strategies

Learning objectives

This course introduces the theoretical and practical fundamentals of active and reactive systems that adapt to time-varying conditions. It covers the principles of dynamic system behavior, system stability, regulation, and feedback control. Students learn how system components interact and respond to changes in boundary conditions and external inputs. The course emphasizes conceptual understanding of optimization strategies, control law design, and the theoretical foundations necessary for modeling adaptive systems, preparing for more advanced control applications in *Control of active and Reactive Systems - Part II*.

Skills

Students will be able to:

- Describe active and reactive system behavior under dynamic conditions:

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Delayed Behavior of Construction Materials	3	Semestre 1	24					

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Delayed Behavior of Construction Materials

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 24

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Recommended to have followed “Coupled energy and mass transfers in porous media”, “Thermodynamics of solid materials – part II porous media”, and “Continuum damage mechanics for quasi-brittle materials”.

Programme/contents

- Hydration and heat release
- Development of the microstructure and physical/mechanical properties
- Autogenous and drying shrinkage
- Basic and drying creep
- Modelling of thermal, chemical, hydric, and mechanical behavior at early-age and long-term

Learning objectives

This course deals with the delayed behavior of construction materials under both environmental (relative humidity, temperature) and mechanical loadings from early age to long-term (hydration, shrinkage, creep). The experimental behavior and the role of the formulation are studied. Chemo-physical mechanisms and existing models are developed to predict material behavior.

- Understand the mechanisms of hydration, shrinkage, and creep in relation to the mix design and the ambient conditions
- Model the early-age and long-term behavior of cement-based materials:
- Analyze the cracking risk by shrinkage restraint through analytical calculations and numerical simulations.

Bibliography

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Thermodynamics of Solid Materials (Part II - Porous Media)	1.5	Semestre 1						

Thermodynamics of Solid Materials (Part II - Porous Media)

ECTS : 1.5

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Thermodynamics of irreversible processes, three-dimensional elasto-(visco)plasticity.

Programme/contents

- Chimio-elasticity, early age concrete.
- Third invariant, Lode angle, general expression of an isotropic criterion function
- Rankine, Hershey-Hosford, (Modified-)Mohr-Coulomb, Willam-Warnke, Mazars criterion functions.
- Marigo (1981) damage model and Lemaitre-Mazars (1980, 1984) damage model for concrete.
- Non associated elasto-plasticity: dilatancy of geo-materials, Drucker-Prager and Willam-Warnke elasto-plasticity.
- Plastic modulus, tangent operator for rate independent Drucker-Prager plasticity.
- Poro-elasto-plasticity, drained and undrained tangent operators.
- Elasto-visco-plasticity of soils.

Learning objectives

- The students will master the three-dimensional, nonlinear material models used for the design of 3D Civil Engineering structures and/or soils subjected to complex loadings.
- Specific constitutive equations are detailed, with a focus on non-isothermal loading conditions and poro-elasto-plasticity. The positivity of the intrinsic dissipation and the fulfillment of the second principle of thermodynamics are checked systematically.

Bibliography

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Digital Image Correlation and Identification (Part II)	1.5	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Digital Image Correlation and Identification (Part II)

ECTS : 1.5

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

To have followed the course “Digital Image Correlation and Identification (part I)”

Programme/contents

Lectures on advanced Digital Image Correlation

- Optimal extractor (noise weighting, covariance, ...)
- Optimal Space-time Digital Image Correlation, Poisson noise
- Mechanical regularization
- Multiview correlation

Lectures on identification based on Digital Image Correlation

- Identification using the Finite-Element Method Updating (FEMU)
- Identification using the integrated Digital Image Correlation (iDIC).
- Integrated Digital Image Correlation for Linear Elastic Fracture Mechanics: measurement of the stress intensity factors KI, KII, supersingular terms

Application to Construction Engineering

- The identification of material parameters using temperature / displacement fields is performed via Finite Element Model Updating (FEMU) for heat transfer applications and/or Continuum Damage Mechanics. Different cost functions are discussed and their relationship to measurement uncertainties is established.

Learning objectives

The course integrates research-oriented procedures dealing with advanced DIC techniques, such as mechanical regularization for robust DIC, space-time

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Structures Subjected to Transient Loads	3	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
■								

Structures Subjected to Transient Loads

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Continuum mechanics, engineering mathematics, fundamental/advanced Finite-Element Method

Programme/contents

- 3D Wave and Shock wave propagation
- Dynamics experimental tests: Split Hopkinson Bar, spalling experiments, impact and penetration tests.
- Impact structural modeling: simplified approach and Finite-Element modeling
- ?Physical aspects of explosions and evaluation of their effects on structures: simplified formulations and Finite-Element modeling.
- Structures subjected to fire: phenomenological analysis and thermo-poro-mechanical modeling of concrete spalling
- ?Numerical methods for interface couplings (fluid–structure interaction) and volumetric couplings (coupled processes in porous media).

Learning objectives

This course explores the scientific principles of extreme loads, such as impacts, blasts, fire, and other extreme events, with an emphasis on their effects on structures. Key topics include 3D wave propagation in solids, experimental and numerical modeling techniques, and the behavior of structures under impact and blast conditions. Students will gain theoretical knowledge to analyze and model the dynamic response of structures under extreme conditions.

Bibliography

- L. Davison, Fundamentals of Shock Wave Propagation in Solids, Springer, 2008
- M. X. H. D. ...

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Reduced and Surrogate Modelling for Construction Engineering	3	Semestre 1						

Reduced and Surrogate Modelling for Construction Engineering

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

mechanics of materials, non-linear finite element method, fundamentals on structural dynamics

Programme/contents

- Parametrized partial differential equations and the challenges of their finite element approximation. Motivation of reduced-order and surrogate/approximated modeling (real-time, high-dimension, multi-query).
- Traditional engineering approaches: static condensation, modal decomposition.
- Various reduced-order and surrogate modeling methods, such as Proper Orthogonal Decomposition (POD), reduced basis methods.
- Sampling strategies.
- Application to non-linear, transient, dynamic responses to parametric or/and random loads.

Learning objectives

- Non-linear finite element analyses often entail significant computational costs, particularly in realistic civil, mechanical, and thermal engineering applications. To enable efficient parametric studies and large-scale simulations, Model Order Reduction (MOR) and surrogate modeling techniques have emerged as essential tools for reducing computational complexity while preserving the essential features of the underlying physical phenomena.
- The course emphasizes both the mathematical foundations and computational implementation of reduced-order and surrogate models, i.e. smart approximated models, with particular focus on their application to computational mechanics and structural dynamics in Construction Engineering.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Continuum Damage Mechanics for Quasi-brittle Materials	3	Semestre 1						

Continuum Damage Mechanics for Quasi-brittle Materials

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Continuum Mechanics, elasto-plasticity, thermodynamics of irreversible processes

Programme/contents

Three-dimensional isotropic (scalar) damage models are first described, such as those proposed by Marigo and Mazars. These models will be criticized from the points of view both of thermodynamics soundness and of representativity of multiaxial responses of cementitious materials.

The question of the tensorial nature of damage is then addressed. Effective stresses are defined, and the principle of strain equivalence is used to couple both elasticity and (visco-)plasticity with damage. A sound thermodynamics formulation of the loading-induced damage anisotropy of quasi-brittle materials is then provided.

- Sought properties of a damage variable
- Effective stress concept (1D, 3D, isotropic damage, anisotropic damage).
- First damage models (Marigo 1981, Lemaitre-Mazars 1980, Mazars 1984).
- Thermodynamics of damage, on the difficulties of ensuring the positivity of the intrinsic dissipation in Continuum Damage Mechanics.
- Loading-induced anisotropic damage of quasi-brittle materials such as concrete.
- Permanent strains due to damage, coupling or not coupling with (visco-)plasticity
- Elements of modeling of cyclic mechanical responses of quasi-brittle materials.
- Visco-damage.
- Quasi-implicit numerical schemes for anisotropic damage models.
- Nonlocal, Eikonal Nonlocal, Gradient damage models, Phase field regularization.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Advanced Structural Modeling	3	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Advanced Structural Modeling

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Fundamentals/advanced Finite-Element Method, background in structural modeling, Engineering mathematics

Programme/contents

This course focuses on the advanced application of the finite element method and non-linear material constitutive models in Construction Engineering. Emphasis is placed on the assessment of resilience under complex loading, up to failure. Key topics include simplified modeling approaches, advanced finite-element techniques, and resilience assessment methods tailored to extreme loading scenarios.

- Multi-fiber beam finite element
- Crack modeling in finite-element simulations of quasi-brittle material and structures: continuous damage model, embedded discontinuities, discrete elements
- Multiscale modeling
- Measures of Robustness and Resilience of structures: Risk-Oriented, Reliability-Based, Energy-Based, Accumulative Damage models... resilience Measures.

Learning objectives

Built on the bases of engineering mathematics, mechanics, and structural analysis, the course “Advanced Structural Modeling” enables students to meet the growing challenges of modeling complex civil constructions up to failure.

Skills

By the end of the course, students will have the expertise to apply sophisticated numerical models that represent the mechanical degradation of Construction Engineering structures in both research and professional settings.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
<u>Advanced Formulations of Rational Mechanics and of its Coupling</u>	3	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	practical class	directed study/practical class
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Advanced Formulations of Rational Mechanics and of its Coupling

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Continuum Mechanics

Programme/contents

- Geometric reformulation of Continuum Mechanics: configurations as embedding, the body as a manifold with border, stresses as powers/1-forms. Strain rate, finite strain, and stress tensors defined by pullback/pushforward operations.
- Conservation laws are formulated using the Lie derivative.
- Differential forms, and their application to modern 4D formulation of electromagnetism.
- Primary and secondary field variables in physics and mechanics, a general Lagrangian framework for couplings formulation, and elements of variation calculus.

Learning objectives

- The main objective is to introduce advanced geometry concept (Riemannian geometry, exterior calculus...) to formulate modern Continuum Mechanics and its coupling with electromagnetism.

Bibliography

- Kolev B., Desmorat R., *An intrinsic geometric formulation of hyper-elasticity, pressure potential and non-holonomic constraints*, *Journal of Elasticity*, 146(1), 29-63, 2021.
- Kolev B., Desmorat, R., *Objective rates as covariant derivatives on the manifold of Riemannian metrics*, *Archive for Rational Mechanics and Analysis*, 248(4), 66, 2024.
- Kolev K., *Éléments de géométrie différentielle à l'usage des mécaniciens*. 2020. hal-

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Scientific Machine Learning - Application to Construction Engineering	3	Semestre 1						

Scientific Machine Learning - Application to Construction Engineering

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Probability theory, Continuum Mechanics, Structural analysis

Programme/contents

- Review of the fundamentals of probability theory: random variables, information entropy, estimation, statistical analysis, stochastic fields
- Probabilistic modeling tools and uncertainty propagation methods, polynomial chaos, Monte Carlo simulation
- Description of random fields from Karhunen-Loève expansion, parametric studies from kriging approaches
- Machine learning: supervised learning for classification and regression, stochastic gradient, universal approximation theorem, two-layer neural networks, deep networks and convolutional networks, unsupervised and semi-supervised learning, autoencoders, generative adversarial networks (GANs)
- Risk assessment by combining a probabilistic approach and machine learning
- Application to a nonlinear structural response in civil engineering.

Learning objectives

Unlike traditional deterministic design methods, which rely on fixed safety factors, probabilistic approaches explicitly account for uncertainty in loads, material properties, geometry, and environmental conditions. Students will learn how to quantify, model, and manage these uncertainties to make more informed and resilient engineering decisions.

In particular, this course explores how probabilistic mechanics and machine learning are combined to

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Experimental Methods	1.5	Semestre 1	6		16			

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Experimental Methods

ECTS : 1.5

Semester: Semestre 1

Detail

Lecture: 6

Practical study : 16

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

cement-based materials microstructure, basic statistics

Programme/contents

- Presentation and discussion on experimental characterization of microstructure and porosity of construction materials: SEM, XRD, TGA, X-ray tomography, MIP etc..
- Analysis of research experimental devices for diffusion and permeation in reactive porous materials.
- Sensor principles used in thermal, diffusion, permeation etc.
- Analysis of real experimental results: influence of Representative Elementary Volume (REV), material parameters variability and sensors uncertainties
- Practical works (4) realized by the students: durability analysis, accelerated chloride diffusion, permeation and micromorphology.

Learning objectives

This course explores different experimental techniques on civil engineering materials in relation to their durability from the microscopic scale to the scale of the materials. Microstructural analysis (mineral phases, liquids and porosity) testing devices used in research applications are described and analyzed (SEM, XRD, TGA, X-ray tomography, MIP etc.). Sensors for the measurements of temperature, relative humidity, pressure etc. are also studied. Effect of Representative Elementary Volume (REV), material parameters variability and sensors uncertainties are discussed. 4 practical works will be realized by the students: durability analysis, accelerated chloride diffusion, permeation and micromorphology.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Low Environmental Impact Materials	3	Semestre 1						

Low Environmental Impact Materials

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Recommended to have followed courses on Eco-conception, on Life Cycle Analysis, on durability of materials, and to have followed the two M2 courses “Durability of building materials” and “Coupled energy and mass transfers in porous media”.

Programme/contents

- This module aligns with the objectives of sustainable development by studying the reduction of the environmental impact of construction through the vision of materials.
- The aim of current research is to develop new cementitious materials that do not require clinker to form a cementitious paste, to recycle steels and concretes from deconstruction, or to recover waste or end-of-life products.
- An introduction to the impact of construction and public works, the challenges and solutions for reducing the sector's carbon footprint, will provide an understanding of current and future issues. Then, the course proposes for the student an overview of the eco-friendly materials with regard to their properties (thermophysical, chemical, mechanical, and hygric properties...), their potential applications, in structures, for public works or in building (new, renovation, and rehabilitation), and their life-cycle analysis or carbon impact. The module will draw on notions of mechanics and structure, deferred behavior and durability, transfers in porous media, and the physical chemistry of reactions.
- Topics covered include: mineral and bio-based additions and substitutions for binders to reduce the use of clinker, which has a high carbon impact; concretes made from recycled aggregates; waste from deconstruction is a major issue; the management of sediments and products from aquaculture: wood as an

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Durability of Construction Materials	3	Semestre 1	24					

Subjects	ECTS Semester	Lecture directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Durability of Construction Materials

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 24

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

cement-based materials microstructure, Coupled energy and mass transfers in porous media, basics in mechanical behavior of structures

Programme/contents

- Presentation and discussion on chemo-physical mechanisms controlling the durability of reinforced concrete structures
- Analysis of the effects of temperature, relative humidity, chemical environment and mix design on the main pathologies of concrete and rebar
- Experimental measurements in laboratory and on field (destructive and nondestructive techniques)
- Modelling of transport phenomena regarding leaching, CO₂, chloride and sulfate transports, internal swelling
- Analysis of structural behavior of degraded reinforced concrete structures due to internal swelling

Learning objectives

This course deals with the prediction of durability of building construction materials and structure. Main chemical attacks are analyzed in regards to environmental conditions (temperature, relative humidity and chemical environments) and material mix design :carbonation, chloride and (internal and external) sulphatic attacks, Alkali-silica reaction and leaching. Chemo-physical mechanisms from the nanostructure to the mesoscopic scales are detailed, in relation to the effects on the structure level. Experiments, multiscale and Multiphysics modeling approaches and design recommendations are analyzed and discussed.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Thermo-Hygro-Morphic Behavior of Materials	3	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
■								

Thermo-Hygro-Morphic Behavior of Materials

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

heat transfer, thermodynamics of materials, basic image processing

Programme/contents

- **Part 1: Multiscale Thermo-Hygro-Morphic Behavior**

The first part of the course focuses on the physical mechanisms and multiscale interactions governing the thermo-hygro-morphic behavior of porous and bio-based materials. The lectures address the coupling between heat, moisture, and deformation processes, as well as the influence of material structure and morphology across different observation scales. Special attention is given to the impact of these coupled phenomena on material aging and biodeterioration, highlighting how environmental conditions accelerate degradation and alter performance over time. Emphasis is placed on understanding experimental characterization methods and their integration into predictive models.

- **Part 2: Morphological Characterization and Numerical Simulation**

The practical sessions introduce digital tools for analyzing and simulating the behavior of real materials. Students first use ImageJ to perform morphological analysis of material microstructures (e.g., porosity, texture, orientation). Based on these results, a 3D simulation using COMSOL Multiphysics is carried out to model the thermo-hygro-morphic responses on an actual material geometry.

Learning objectives

- The course aims to study, through innovative approaches, the hygro-morphic behavior in porous materials in general, and bio-based

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Energy in Construction	3	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Energy in Construction

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

- Fundamentals of thermodynamics and heat transfer
- Basic building physics and materials science
- Elementary knowledge of renewable energy systems (recommended)

Programme/contents

- Thermodynamic behavior of building envelopes and high-performance components, including multi-layered insulation and glazing
- Passive and hybrid strategies: free cooling, natural ventilation, thermal mass, daylighting, and energy management
- Integration of renewable energy systems and energy storage for net-zero and positive-energy objectives
- Modeling, simulation, evaluation, and research applications in sustainable and energy-positive building systems

Learning objectives

This course provides an advanced understanding of building energy performance, with a focus on thermal dynamics, energy efficiency, and integration of renewable energy systems. It combines theoretical and applied perspectives on heat transfer, thermodynamic behavior of building envelopes, and dynamic interactions between building components and environmental conditions. The course investigates strategies to achieve net-zero or energy-positive buildings, including passive cooling, free cooling, thermal storage, and active energy management. Emphasis is placed on modeling, simulation, and optimization of energy flows, integrating component-level efficiency with system-level performance, and evaluating the interactions between renewable energy sources and building operation. The course also adopts a research-oriented approach, enabling students to develop scientific expertise in the analysis, design, and performance

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Control of Active and Reactive Systems (Part II)	1.5	Semestre 1						

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Control of Active and Reactive Systems (Part II)

ECTS : 1.5

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

- Basic numerical methods and simulation tools
- Completion of Part I
- Dynamics and control theory (recommended))

Programme/contents

- Advanced modelling and simulation of controlled energy, mechanical, and transport phenomenon
- Optimization of component parameters and material responses under dynamic conditions
- Coupling control with heat, mass, and energy transfer processes
- Stability analysis and design of predictive, adaptive, and robust control laws
- Case studies: adaptive building systems, active damping,
- Research applications: design and validation of innovative control strategies for multi-physics systems

Learning objectives

This part (II) emphasizes advanced theoretical and applied aspects of active and reactive systems. It covers modeling of dynamic multi-physics systems, predictive, adaptive, and robust control strategies, and stability analysis under time-varying boundary conditions. The course develops skills in optimization of building system components and material responses, integrating control theory with energy, mechanical, and transport processes. It fosters research-oriented expertise in designing, simulating, and validating complex control strategies, bridging theory with practical applications in engineering and smart infrastructure.

Skills

Students will be able to:

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
From Experiments to Modeling and Simulation for Sustainable Construction	3	Semestre 1	12					

Subjects	ECTS Semester	Lecture directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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From Experiments to Modeling and Simulation for Sustainable Construction

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 12

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Experimental methods, durability, life cycle analysis, cement-based materials microstructure, modelling of transport phenomena in porous materials (energy and mass), numerical methods

Programme/contents

- Analysis of experimental results in steady state and transient conditions. Identification of material parameters (diffusivity, permeability).
- Several projects will be proposed to students, and each group will have to choose a topic.
- Proposal of an ionic (chlorides) or gaseous (CO₂) diffusion model taking into account porosity, then composition parameters. Numerical implementation in the linear then nonlinear case. Multi-criteria analysis to identify the optimal composition and geometry.
- Proposal of a model taking into account liquid water permeation (drying) and gas tightness. Coupling between the two models. Application to a containment building for nuclear reactors, to predict its service-life.

Learning objectives

The objectives of this course are to apply the skills acquired in the field of experimental methods and modeling of transport phenomena in porous materials, as well as in the field of numerical methods. The experimental results (permeability and ion diffusion) obtained during the practical work in the experimental methods module will be used to predict the lifespan of a reinforced concrete structure (bridges, nuclear power plants, dams, etc.). A model will be developed by proposing hypotheses on

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Reduced Models for Transient Thermal Problems	3	Semestre 1						

Reduced Models for Transient Thermal Problems

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Basic heat transfer, basic coding

Programme/contents

- **Part 1: Direct Simulation.**

After a brief review of heat transfers, various numerical methods used to solve the heat equation are reviewed, followed by a presentation of modal methods. The course alternates lectures and practical classes during which students code methods covered in class.

- **Part 2: Inverse Problems.**

The inverse problem is presented. Using the previously obtained reduced model, the objective is to identify a parameter of the problem, either a material property or a time-varying boundary condition.

Learning objectives

- In addition to its obvious applications, heat transfer is omnipresent for the design of systems, whether in thermomechanics or metrology. Its precise consideration involves the numerical solution of the heat equation, which might require significant memory space and computation time. This often prohibits its implementation in iterative process encountered in inverse problems. These latter aim to determine causes or parameters from observed effects, and are crucial in various scientific and mathematical fields.
- The course is a numerical/code module applied to heat transfer. Its objective is to present modal reduction methods for the numerical solution of the heat equation, as well as their application to inverse problems such as parameter identification.

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Energies éoliennes et marines	1.5	Semestre 1	6	6	4			

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Energies éoliennes et marines

ECTS : 1.5

Semester: Semestre 1

Detail

Lecture: 6

Practical study : 4

Directed study: 6

Language(s) of instruction

Français

Remote teaching

non

Prerequisites

Mécanique des fluides élémentaire (bilans de masse, de quantité de mouvement, d'énergie. Théorème de Bernoulli).

Programme/contents

- Aérogénération : historique, développement actuel et principes de base
- Eolienne standard : fonctionnement, rendement instantané et production annuelle
- Energies marines : éolien off-shore, hydroliennes et dispositifs houlo-moteurs

Des études de cas et des dimensionnement sont proposés sous forme d'exercices de TD et d'une séance de TP numérique encadré.

Learning objectives

Le cours présente les grands principes, éprouvés ou émergents, sur lesquels les machines de production d'énergie renouvelable éolienne et marine sont conçus, avec un accent mis sur la modélisation en aérodynamique des rotors et sur la prédiction de l'énergie annuelle produite. Continuellement remis à jour, il aborde aussi l'actualité très fournie dans ces domaines.

Skills

- Compréhension et prévision de la conversion mécanique dans une machine de production d'énergie renouvelable éolienne ou marine
- Dimensionnement et design d'une machine de production d'énergie renouvelable éolienne ou marine

Détermination de la puissance et du couple d'une machine de production d'énergie renouvelable éolienne ou marine

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Calcul haute performance	1.5	Semestre 1	9	6				

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	practical class	directed study/practical class
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Calcul haute performance

ECTS : 1.5

Semester: Semestre 1

Detail

Lecture: 9

Directed study: 6

Language(s) of instruction

Français

Remote teaching

non

Prerequisites

Base de la programmation (Python), maitrise d'un environnement sous Unix.

Programme/contents

- Introduction générale sur le calcul haute performance
- Bases de l'utilisation d'un super-calculateur (Slurm)
- Fonctionnement de la bibliothèque MPI pour l'écriture d'un programme parallèle
- Etude de la performance.

Learning objectives

Ce cours est une introduction à la programmation parallèle appliquée au domaine scientifique. Les ressources de calcul nécessaire à la résolution de nombreux problèmes physiques nécessitent l'utilisation de super-calculateurs. Les super-calculateurs sont des machines parallèles composées d'un grand nombre d'unités de calcul (processeur, GPU) connectées au travers d'un réseau extrêmement rapide. Le défi du Calcul Haute Performance est de faire travailler efficacement ensemble toutes ces unités de calcul.

Overall organisation

L'UE s'organise autour de 4 séances de 3h45 avec une alternance de cours et de TD. L'UE est évalué par un projet.

Bibliography

- Cours de l'IDRIS sur MPI : <https://www.idris.fr/formations/mpi/>

Type of assessment

Evaluation Continue non Intégrale

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Volumes Finis	3	Semestre 1	10	10	10			

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	practical class	directed study/practical class
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Volumes Finis

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 10

Practical study : 10

Directed study: 10

Language(s) of instruction

Français

Remote teaching

non

Prerequisites

Méthodes numériques (interpolation, différenciation, analyse de stabilité, ordre & consistance, différences finies)

Résolution de systèmes linéaires (méthodes directes, méthodes itératives)

Bases de la programmation (Fortran ou C, Python)

Programme/contents

- Introduction à la méthodes des Volumes Finis et principes de base
- Résolution de problèmes modèles : équation de Laplace, équation d'Helmholtz
- Problème de convection-diffusion : schémas Upwind, Power-Law, Quick, TVD, ...
- Problématique du couplage vitesse-pression : introduction des spécifités des écoulements incompressibles, maillages décalés, méthodes stationnaires (SIMPLE, PISO) et instationnaires (méthode de projection)
- Méthodes de résolution des systèmes linéaires : méthodes directes (algorithme de Thomas), méthode itératives (multi-grille)
- Introduction aux méthodes de maillage adaptatif
- Implémentation d'un schéma de résolution de l'équation de Navier-Stokes pour des configurations académiques (cavité entraînée, cavité différentiellement chauffée).

Learning objectives

La méthode des Volumes Finis est une méthode classique pour discrétiser les équations régissant les écoulements de fluide. Lors de ce cours, une introduction à cette méthode sera donnée, en présentant les principales caractéristiques et propriétés de la méthode, d'abord sur des équations modèles (transport de la chaleur, stationnaire puis

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Modèles adaptatifs et approches pilotées par les données	3	Semestre 1	24		6			

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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Modèles adaptatifs et approches pilotées par les données

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 24

Practical study : 6

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Mécanique des milieux continus, méthodes des éléments finis, analyse fonctionnelle, notions de programmation.

Learning objectives

La modélisation et la simulation numérique sont au coeur des activités modernes en recherche et ingénierie. De ce fait, et pour assurer la fiabilité des résultats de simulation, la maîtrise des modèles et des calculs est une problématique fondamentale.

L'objectif est de calculer juste au juste coût. Le cours vise à présenter les concepts de base utilisés pour atteindre cet objectif, ainsi que leur mise en œuvre pratique.

Les outils d'estimation d'erreur de discrétisation et d'adaptation de maillage dans le cadre de la méthode des éléments finis apparaissent comme précurseurs pour la vérification des modèles numériques.

Cependant, la thématique englobe à présent un spectre beaucoup plus large d'outils impactant toute la chaîne de modélisation. On peut citer par exemple la modélisation multi-fidélité, avec contrôle de l'erreur du modèle mathématique dans les techniques de réduction de modèle et de couplage multiéchelle par exemple, ou la modélisation pertinente en lien avec la richesse de l'information expérimentale (quantité et niveau de bruit des mesures) dans la résolution de problèmes inverses et l'assimilation de données. Toutes ces composantes sont abordées dans le cours.

Overall organisation

Le cours présente d'abord les techniques classiques d'estimation d'erreur (basées sur les résidus d'équilibre, les techniques de lissage, ou l'erreur en

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Stratégies de calcul multi-échelle et méthodes de décomposition de domaine	3	Semestre 1	24		6			

Stratégies de calcul multi-échelle et méthodes de décomposition de domaine

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 24

Practical study : 6

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Mécaniques des milieux continus, formulations variationnelles, méthodes des éléments finis, algèbre linéaire, méthodes numériques pour la résolution des systèmes linéaires

Learning objectives

Dans ce cours sont présentées les stratégies de calcul multiéchelles par méthodes de décomposition de domaine (DDM) sans recouvrement. Les approches primales, duales et mixtes sont présentées dans le cadre de la mécanique des structures en élasticité linéaire. Les formulations continue et discrétisée correspondantes ainsi que leur mise en œuvre technique sont détaillées :

Présentation du problème et enjeux : problème de référence sous-structuré, généralités sur les DDM (mise en donnée, enjeux, environnement matériel) ;
 Approches primale, duale et mixte : approches de Schur primale et duale, approches mixtes basées sur un Lagrangien augmenté ou sur un algorithme à deux directions de recherche ;
 Stratégies de calcul multiéchelle par DDM, introduction du problème grossier : tests de qualification d'une DDM, préconditionnement du problème d'interface (BDD, FETI, DDM mixte basée sur la LATIN), résolution du problème grossier (solveur de Krylov, gradient conjugué projeté...) ;
 Introduction au traitement par DDM des problèmes non-linéaires : approches classiques, méthode de Newton Krylov Schur, technique de relocalisation non-linéaire, approche globale en temps de type LATIN.

Overall organisation

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
Scientific Machine Learning and applications to Mechanics	3	Semestre 1	20		10			
■								

Scientific Machine Learning and applications to Mechanics

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 20

Practical study : 10

Language(s) of instruction

Anglais

Remote teaching

non

Type of assessment

Evaluation Continue non Intégrale

[High](#)

[Performance](#)

[Computing in](#)

[Solid Mechanics](#)

■

High Performance Computing in Solid Mechanics

ECTS : 3

Semester: Semestre 1

Detail

Lecture: 24

Directed study: 6

Language(s) of instruction

Anglais

Remote teaching

non

Type of assessment

Evaluation Continue non Intégrale

[Autonomous](#)

[Learning](#)

3

Semestre

1

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class
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■

Autonomous Learning

ECTS : 3

Semester: Semestre 1

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Disciplinary courses in the M2 program

Learning objectives

Autonomous Learning instruction of a scientific thematic in the skills of a University Professor of the M2 program

Type of assessment

Détail renseigné au niveau Élément Constitutif

Research Training

Subjects	ECTS	Semester	Lecture	directed study	practical class	Lecture/directed study	Lecture/practical class	directed study/practical class	distance learning
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[State-of-the-Art Report](#)

7

Semestre
2

State-of-the-Art Report

ECTS : 7

Semester: Semestre 2

Detail

Project : 200

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Disciplinary courses of the M2 program

Programme/contents

Each student carries out individual bibliography research on a scientific subject, under the guidance of a member of Laboratoire de Mécanique Paris-Saclay (LMPS), UMR CNRS 9026.

Learning objectives

Students are trained in scientific methodology, including bibliographic analysis and the presentation of scientific results.

Type of assessment

Evaluation Continue Intégrale

[Research for All](#) 2 Annualisé



Research for All

ECTS : 2

Semester: Annualisé

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Disciplinary courses of the M2 program

Learning objectives

This project aims to prepare students to communicate scientific results related to cutting-edge topics (writing an abstract, a list of highlights, a graphical abstract).

Type of assessment

Evaluation Terminale

[Scientific](#)

[Training](#)

[Period](#)

21

Semestre

2



Scientific Training Period

ECTS : 21

Semester: Semestre 2

Detail

Project : 630

Language(s) of instruction

Anglais

Remote teaching

non

Prerequisites

Disciplinary courses of the M2 program

Programme/contents

Research internship

Learning objectives

The internship enables the student to gain initial research experience within a research group. A research project, including a bibliography and own investigation (analytical development, modeling, or experiment), is carried out. A few collective and individual guidance sessions are organized by the Master program.

Type of assessment

Evaluation Continue Intégrale

[Opening Course](#)

2

Annualisé

Opening Course

ECTS : 2

Semester: Annualisé

Language(s) of instruction

Anglais

Remote teaching

non

Overall organisation

After agreement with the heads of the M2 programs, the opening course(s) can be chosen either among the Master programs lists of courses, or can be chosen from another M2 or among those proposed by the Graduate School *Engineering and System Science*.

Examples of Opening Courses are:

- Course “UE Sport” (2.5 ECTS)
- Autonomous-Learning course (3 ECTS)
- Course from other M2 programs.

Type of assessment

Détail renseigné au niveau Élément

Constitutif

[Second](#)

[Opening](#)

2

Annualisé

[Course](#)



Second Opening Course

ECTS : 2

Semester: Annualisé

Language(s) of instruction

Anglais

Remote teaching

non

Overall organisation

After agreement with the heads of the M2 programs, the opening course(s) can be chosen either among the Master programs lists of courses, or can be chosen from another M2 or among those proposed by the Graduate School *Engineering and System Science*.

Examples of Opening Courses are:

- Course “UE Sport” (2.5 ECTS)
- Autonomous-Learning course (3 ECTS)
- Course from other M2 programs.

Type of assessment

Détail renseigné au niveau Élément

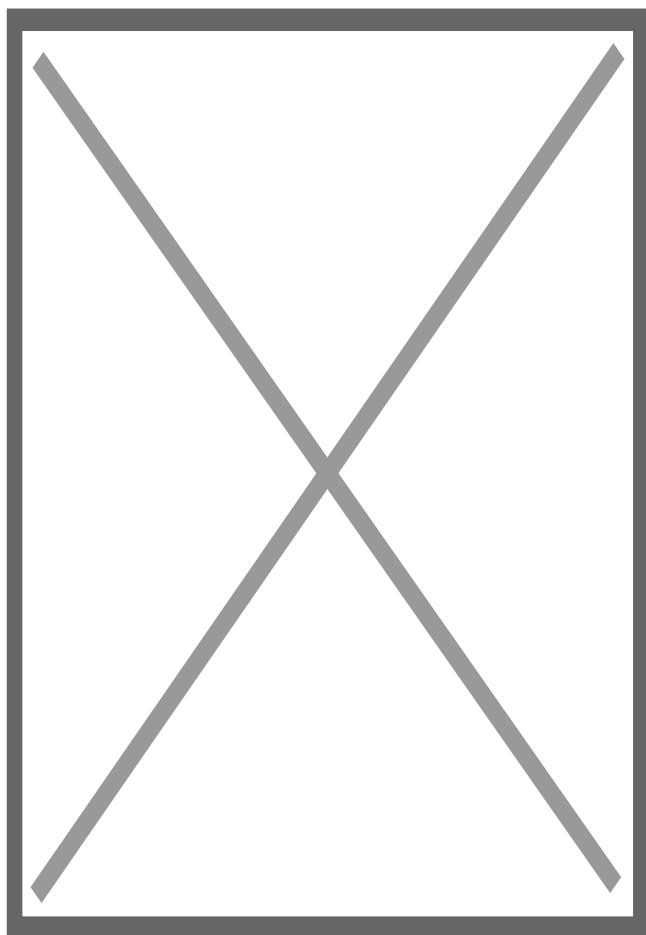
Constitutif

Teaching Location(s)

GIF SUR YVETTE

Training campus

Javascript est requis pour visualiser cette carte.



Saclay Moulon

Saclay / Gif-sur-Yvette / Orsay

Bus 4606 / 4609 / 4611 / 5154

RER B Le guichet

[Voir](#)

Student restaurant (CROUS)

Library

Sports facilities

Student residence

Contact

- **Kamilia ABAHRI**
- **Farid BENBOUDJEMA**
- **FAU Amélie**
- **Rodrigue DESMORAT**

- **Rachid BENNACER**
- **Léa COCO**

<http://www.universite-paris-saclay.fr/formation/master/energie/m2-advanced-materials-structure-and-energy-sustainable-construction>