Topics offered to students by other master's programs

TARGET PROGRAM

Civil Engineering

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Master : Chemical & Materials engineering - M-IRMAE

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

• Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.

• High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.

• Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

- Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- Monthly meeting with the team to verify the progress and discuss follow-up
- Final presentation

References

[1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," Int. J. Heat Mass Transf., vol. 215, p. 124466, 2023.

[2]. J. Massing, G. Mutschke, D. Baczyzmalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," Electrochimica Acta, vol. 297, pp. 929–940, 2019.

Language	EN (english)
Number of topics	1

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Sustainable iron metal production by direct electroreduction of iron ore

Program : Chemical & Materials engineering - M-IRMAE

Description

Steel production accounts for more than 8% of global emissions and sustainable steel production is key to achieve a decarbonized economy. The direct electroreduction of iron oxide to produce metallic iron (ULCOS project) is truly a fascinating field of research and offers a breakthrough alternative to the existing status quo of blast furnace based iron production. The reaction happens in alkaline media and the mechanism of electroreduction -ie, solid state direct reduction is yet to explored in detail. Furthermore, a lot of other sources such as bauxite residue can be directly used to produce metallic iron via this method. The student will work on firstly understanding the fundamental reaction mechanism of direct electroreduction of iron from iron oxide in alkaline media.

Promotor: Prakash Venkatesan (Prakash.venkatesan@ulb.be)

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRARE, M-IRCBS, M-IRCNE
Number of topics	2

Supervision

Supervisor : Prakash Venkatesan (prakash.venkatesan@ulb.be)

Topics offered to students by other master's programs

TARGET PROGRAM

Civil engineering

Master’s program offering the topic: Architectural engineering - M-IRARE

Incorporating Sustainability in the design process of products, processes and businesses.

Description

How to design products that have a better impact on environment, social and economy? This thesis starts with a state of art review of methods for 'Design for Sustainability'. What are methods to decision on sustainability and what are the remaining challenges and pitfalls? The aim of the thesis is to formulate a novel way to embed sustainability in the decision process of companies and link it to existing methods for corporate sustainability reporting.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IRCNE, M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI
Nombre de sujets	1

Supervision

Supervisor : Messagie Maarten (maarten.messagie@vub.be)

Master's program offering the topic: Biomedical engineering - M-IRCBS

Bistable structures for bronchoscopy

Description

Context: Bistable structures enable multi-equilibrium states without the energy consumption ex-cept for switching from state to state. They are key in many applications, among which building engineering or soft robotics (https://www.non-linearity.com/conference/ftn2026). At small scale they could provide extra degrees-of-freedom to orientate and position endo-scopic cameras such as the video-endoscope developed by Lys Medical.
Objectives: This master thesis aims to design and numerically model a bistable structure actuated by hydrogel actuators.
Methods: Literature review. Finite elements modelling (Batir). Design. Fabrication and characteriza-tion (Tips).
Prerequisites:

- Mechanical design
- Interest for civil, mechanical, biomedical and bio-engineerin

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Chemical & Materials engineering - M-IRMAE

Towards Low-Carbon Construction Materials: Linking Strength to Carbonation in CO_2-Cured Steel Slag

Description

Cement production is one of the largest industrial sources of CO_2, responsible for roughly 8% of global emissions. Unlike most industries, more than half of these emissions come not from energy use but from the chemical process itself — the decomposition of limestone — meaning that switching to renewable energy alone cannot solve the problem.

A promising alternative lies in steel slag, a by-product of the steel industry that is currently underused. When mixed with water and exposed to CO_2, certain minerals in steel slag react to form stable carbonates that bind the material together and give it mechanical strength. This approach offers a double environmental benefit: it avoids the need for conventional cement, and it actively locks CO_2 into the final product, effectively turning a greenhouse gas into a building material.

However, making this process reliable remains a challenge. The carbonation reaction is sensitive to many interacting parameters — CO_2 concentration, humidity, temperature, and exposure time — and achieving more carbonation does not always lead to higher strength. This master's thesis tackles these questions by combining complementary characterisation techniques. Impulse excitation — a non-destructive method that measures stiffness by analysing the natural vibration frequency of a specimen — offers a quick window into mechanical performance without breaking the sample, while conventional compression testing provides direct strength values. Together, they allow the investigation of the process parameters and sample handling affect mechanical outcomes. Thermogravimetric analysis (TGA), which tracks mass loss as carbonates decompose under controlled heating, is then used to determine the actual degree of carbonation and relate it to the measured strength.

A key part of the work will be developing sampling and testing protocols that are not only accurate and reproducible, but that could ultimately help bring CO_2-cured construction materials from the laboratory to real-world application.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRARE, M-IRCNE
Nombre de sujets	1

Supervision

Supervisor : Rahier Hubert (hubert.rahier@vub.be)

Master’s program offering the topic: Chemical & Materials engineering - M-IRMAE

Exploring how fillers affect the strength and heat resistance of new cement mixes

Description

The construction industry, a significant contributor to global carbon emissions, faces a pressing need to reduce its environmental footprint. Traditional cement production processes release an enormous amount of carbon dioxide, due to the conversion of calcium carbonate to calcium oxide which requires high temperature (fossil fuels burnt). Additionally, conventional cement-based mortars exhibit compromised mechanical performance at elevated temperatures, this is attributed to the decomposition of Calcium Silicate Hydrate (CSH) which starts at around 300 °C. Alkali activation is a promising alternative, using industrial waste materials from sectors like iron or copper industries as precursors; this allows to reduce cement consumption, so less CO2 is emitted, and enhance mechanical and thermal properties. However, the thermal resistance and mechanical strength of alkali-activated materials are influenced by various factors such as water/binder ratio, binder/filler ratio, and the type of filler used (e.g., sand, granite, limestone, chamotte). Moreover, the different chemical compositions of potential raw materials, such as metakaolin, fly ash, and blast furnace slags, can significantly impact thermal resistance. The choice of alkali cation could also play an important role in the thermal behaviour of the materials.

The main objective of this master's thesis is to investigate the influence of different fillers on the mechanical and thermal properties of alkali-activated mortars. Initially, a literature review will be conducted to provide a ground understanding of the topic. Then, an alkali activation system will be selected: precursors, activators, and different types of fillers. Formulation of the system will be started by assessing the reactivity through isothermal calorimetry. The mechanical characterization of the formulations will be done with flexural strength, compressive strength, and Young's modulus testing to evaluate mechanical properties. The residual mechanical properties of materials after exposure to high temperatures (up to 1000 °C) will be assessed, and the study of crack formation using acoustic emission analysis might be a test to be performed as well. Additionally, the evolution of Young's modulus during heating, from room temperature to high temperatures, will be monitored. Microstructural changes in the different compositions will be investigated to provide insights into the elemental mechanisms influencing the mechanical and thermal behaviour of the alkali-activated mortars.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRARE, M-IRCNE
Nombre de sujets	1

Supervision

Supervisor : Rahier Hubert (hubert.rahier@vub.be)

Master’s program offering the topic: Civil engineering - M-IRCNE

Investigation of the Micro-Profiling Effect on the Mechanical Behaviour of Thin Steel Sheeting

Description

Cold-formed steel sheeting is widely used in lightweight construction systems such as roofs, floors, and composite decks. In addition to the primary corrugation geometry that provides global bending stiffness, manufacturers increasingly introduce micro-profiling (small-scale surface indentations or ribs) in the flanges of the sheeting (Figure 1). These micro-profiles are intended to improve local stability (delay local buckling), and increase stiffness without significantly increasing material usage [1,2]. Composite slabs are outside the scope of this thesis; consequently, indentations related to composite action are not considered.

Two representative industrial products illustrate this concept:

Figure 1: JI 106-250-750 (Joris Ide) left and – T130M-75L-930 (Ruukki) (right) featuring light micro-profiling on the top flange, and on both top and bottom flanges, respectively.

While the global structural behaviour of profiled steel sheeting is well documented, the mechanical contribution of micro-profiling remains insufficiently quantified. Initiation and development of local buckling modes in the compressed flanges under bending loading will be studied in this thesis at the small scale.

This thesis is embedded in a broader research framework studying acoustic roof decking as sustainable and environmental friendly solution with light weight and low end-of-life impacts.

In this thesis, detailed FE models of micro-profiled, small-scale panels will be developed and used for a parametric study allowing a direct comparison between micro-profiling effects for different micro-profile geometries. To ensure reliability, the developed numerical models will be experimentally validated through compression tests on small-scale panels incorporating micro-profiling.

Research Objectives

To quantify and understand the mechanical influence of micro-profiling on thin cold-formed steel sheeting through validated finite element modelling.

1

Geometrical Characterisation and Performance

o

Digitally reconstruct representative micro-profiling geometries of selected sheeting types.

o

Develop parametrised small-scale panel models incorporating realistic micro-profile

details. Systematically vary:

- Depth,
- Spacing,
- Shape,…

o Quantify using finite element modelling the influence on:

- Bending stiffness,
- Elastic buckling resistance,
- Load redistribution mechanisms.

2 Experimental Validation

Manufacture or obtain small-scale micro-profiled panels.
Conduct controlled compression tests.
Measure:
Load–displacement response,
Buckling modes,
Strain development.

3 Validation

Calibrate and validate FE models against experimental results.
Summarize insights.

References

[1] R. Studziński, Z. Pozorski, A. Garstecki (2015). Structural behavior of sandwich panels with asymmetrical boundary conditions. Journal of Constructional Steel Research 104: 227–234

[2] X. Ma, J.W. Butterworth, G.C. Clifton (2008). Unilateral contact buckling of lightly profiled skin sheets under compressive or shearing loads. International Journal of Solids and Structures, 45: 840–849

Objectives of the master thesis

This research is expected to:

- Give a well-structured comprehensive overview of the state of the art.

-
Provide a mechanistic understanding of how micro-profiling modifies elastic stress fields in thin steel sheeting.
-
Establish validated finite element modelling strategies for small-scale micro-structured panels.
-
Clarify the relative structural efficiency of micro-profiling compared to flat panels.
-
Deliver quantitative design-oriented insights for manufacturers aiming to optimise sheet geometry without increasing material thickness.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IREMR-A, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Pyl Lincy (Lincy.Pyl@vub.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Mechanical characterization of non-linear materials to be used as miniaturized actuators

Description

Context: Active soft matter can be used as an actuator in microrobotics. It can deform under an external stimulus such as light, heat, or pH to generate a mechanical output (force and dis-placement). At the microscale, these smart materials can be 3D printed without assembly. In the lab, we use the two-photon polymerization method (2PP) to shape 50µm soft actua-tors out of a thermo-responsive polymer (pNipam = poly(N-isopropylacrylamide)). These active cubes demonstrate bending, contraction, twist, or shear deformation in a heated wa-ter bath [1]. Their mechanical performances such as Young modulus, force-displacement characteristics, or response time must now be characterized.
Objective: The aim of this thesis is to use a setup to measure the force-displacement characteristics of such actuators and to analyze the indentation data with the help of a finite element ap-proach to decouple the elastic parameters (Young modulus, Poisson coefficients) from the visco-elastic parameters.
Methods: Literature review on modeling soft material at microscale. Develop a code to analyze the experimental data. Eventually, the results obtained may be supplemented and compared with data obtained with an environmental AFM, at UMons, and/or a nanoindentation sys-tem [4], at EMPA (Thun, Switzerland).
Prerequisites: Numerical methods

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : LAMBERT Pierre (pierre.lambert@ulb.be)

Master’s program offering the topic: Civil engineering - M-IRCNE

Investigation of thermal fields during the manufacturing of 3D printed composites

Description

Context of the master thesis

3D printed composites combine the flexibility of additive manufacturing with the improved mechanical properties of composite materials. An important aspect of the printing process is the thermal field that develops during material deposition, as it directly affects interlayer bonding, residual stresses, and defect formation. Quantifying these thermal fields allows better control of printing parameters and leads to improved print quality and structural performance. A clear understanding of the thermal behavior during printing is therefore essential for improving the reliability of 3D-printed composite components1.

The master's student will employ infrared cameras during the printing of simple structures to capture thermal fields and use them to perform finite element analysis (FEA). This approach facilitates learning the intricacies of the 3D printing process, camera setup, and subsequent data post-processing along with the basics of FEA. The post processing will be achieved in Python using image processing techniques and the FEA in the ABAQUS software. Through this master thesis, the student will gain a holistic understanding of: additive manufacturing (printing process), thermal mechanics (influence of thermal fields), and FEA, equipping them with valuable skills for future endeavors in technology and engineering fields.

Fig. 1 Thermal image during printing.

References

1)
Cattenone, A., Morganti, S., Alaimo, G., & Auricchio, F. (2019). Finite element analysis of additive manufacturing based on fused deposition modeling: Distortions prediction and comparison with experimental data. Journal of Manufacturing Science and Engineering, 141(1), 011010.

Objectives of the master thesis

- Measure transient thermal fields during the 3D-printing process using infrared cameras.
- Process infrared data using Python-based image processing techniques.
- Analyze the influence of printing parameters on the evolution of thermal fields.
-

Implement simplified thermal finite element models in Abaqus using experimentally obtained data.

-

Assess the implications of thermal fields on the printing process.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IREMR-A, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Pyl Lincy (Lincy.Pyl@vub.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Automating 3D Geometric Measurement of Mechanical Test Benches Using Structured Scanning and Point Cloud Analysis

Description

Mechanical test benches must meet strict geometric tolerances to ensure that experimental measurements accurately reflect material and structural behavior rather than setup artifacts. Verifying these tolerances manually is a slow and error-prone process that becomes particularly burdensome when benches are frequently reconfigured or when high-precision applications demand exhaustive dimensional audits. This thesis designs and validates an automated system that acquires the complete 3D geometry of a mechanical test bench using a scanning sensor mounted on a motorized positioning stage, and processes the resulting point cloud data to extract quantitative geometric parameters without manual intervention. The system plans acquisition trajectories to ensure full coverage, registers multi-view scans into a unified coordinate frame, and computes deviations from CAD reference geometry to identify misalignments, deformations, and tolerance violations. Output is presented as an interactive 3D deviation map and a structured dimensional report, giving mechanical engineers a rapid, reproducible qualification tool that replaces manual measurement campaigns and supports traceability in accredited testing environments.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Feasibility study of Probability of Dectection for new Structural health monitoring solutions of 3D printed aeronautical structures.

Description

Context of the master thesis:
Structural health monitoring (SHM) is an emerging technology for continuously monitoring of the structural integrity of the structural system. SHM has a high added value potential for different industries. A new innovative crack detection SHM system has been developed within the acoustics and vibration research group. The technological readiness level of the new SHM system can be extended if the Probability of Detection (PoD) is clarified. A PoD allows the user to verify the likelihood of detecting cracks with a certain length by the SHM system. The main objective for the Master thesis student would be to investigate the feasibility and applicability of the PoD concept for the developed SHM system in numerically or experimentally manner.

Tasks:

- Literature study of existing SHM and NDT (Non Destructive Testing) system for aeronautical structures and additive manufacturing.
- Literature study of Probability of Detection (PoD) for SHM and NDT operational systems.
- Definition of potential approaches.
- Development of experimental setup or/and numerical simulation in order to verify working principles.
- Selection of potential PoD approach.
- Implementation of an initial verification tests or/and numerical simulation procedure to generated data to support a PoD.
- Conclusion on the feasibility of the PoD approach for the new SHM concept.

If time permits the research can be extended to 3D printed aeronautical structures. Further details regarding the concepts can be provided by the contact person on request.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IREMR-M
Nombre de sujets	2

Supervision

Supervisor : De Baere Dieter (dieter.de.baere@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development of aeronautical demonstrator 3D printed component with integrated Structural health monitoring solution.

Description

Context of the master thesis:
Structural health monitoring (SHM) is an emerging technology for continuous monitoring of the structural integrity of the structural components. They can unleash the full potential of 3D printed (additive manufactured AM) components and in the long run improve our carbon footprint. The technological readiness (TRL) level of an in house developed SHM system can be further increased by proving its applicability also on a demonstrator level besides the current available coupon level results. The main objective for the Master thesis student would be to investigate and develop new designs with integrated SHM technology of typical mechanical system such as lug bolt configurations. The objective is to prove numerically and if time permits also experimentally the increase of the TRL level.

Tasks:

- Literature study of additive manufacturing and topological optimization.
- Manual redesign of the component exploiting the design freedom offered by AM with integrated SHM solution.
- Static hand calculations in conjunction with Finite Element Analysis of manually optimized design solutions.
- Static Finite Element Analysis of topology optimized design solutions.
- Crack growth analysis at one specific location on the component.
- Analysis of the performance of a structure with an without integrated SHM solution.
- Conclusion on the increase in TRL level.

If time permits the research can be extended with printing of the component and experimental testing. Further details regarding the concepts can be provided by the contact person on request.

See also external link

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IREMR-M
Nombre de sujets	2

Supervision

Supervisor : De Baere Dieter (dieter.de.baere@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Digital twin simulations of offshore wind turbines

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behaviour. Digital twin are more and more used in the wind industry to predict remaining lifetime, predictive maintenance, and structural integrity. Commonly differentiated in data-driven digital twins, which represents the structure completely based measured inputs, and physics based digital twins, which are build based on existing physical relations. Through their rooting in known physical relations, physics-based digital twins often provide better transparency of their behaviour.

- Objective:
In this Master Thesis you will validate the physics-based digital twin of an offshore wind turbine in the Belgian North Sea with real-world data using the aeroelastic simulation software ASHES.

- Prerequisites/special skills (optional)
An interest in structural dynamics and programming is desired. A good knowledge of numerical methods such as the finite element method as well as prior experience with aeroelastic software such as OpenFast can be advantageous. This master thesis gives you the opportunity to learn about the modelling and dynamic behaviour of Offshore Wind Turbines as well as the work of OWI-lab in the structural health monitoring of wind turbines.

- Other information:
This topic is an umbrella topic in which direction can be given aligned with the student's interests and skillset. E.g. the focus can be put on the control of the turbine, the soil-structure interaction, the performance under anomaleous behaviour, the automatic integration between database and simulation, ...

Your thesis work builds on past master thesis's and starts from their latest findings.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Experimental testing of a monitoring hardware for application in floating offshore wind turbines.

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behavior. Floating Offshore Wind Turbines (FOWT) refer to offshore wind turbines mounted on floating platforms, allowing them to be deployed in deeper waters where fixed-bottom turbines are not feasible.

- Objectives of the master thesis;
This master's thesis focuses on building and testing a small-scale experimental setup to evaluate a monitoring hardware system (GNSS/IMU). The objective is to assess the hardware's ability to provide accurate position for an instrumented device—such as a scaled FOWT. When combined with other sensor types, this data will help us better understand the motion characteristics of FOWTs and how they relate to mooring line tensions and overall system dynamics. This project is conducted in collaboration with 24SEA, a company specializing in monitoring solutions for offshore wind turbines.

- Prerequisites/special skills (optional)
An interest in structural dynamics, experimental work and programming is desired. The thesis also includes working with sensors and hardware, and doing experimental validation of the sensor setups. A thesis suitable for someone with a strong 'MacGyver'/'Maker' - spirit.

- Other information
This thesis might require you to travel occassionally to 24SEA, situated just outside Brussels.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Mechanical characterization of polymeric soft materials to be used as miniaturized actuators

Description

Context: Soft matter is used as an actuator in microrobotics. It can deform under an external stimu-lus (light, heat, or pH…) to generate a mechanical output (force and displacement). In the lab, we utilize the two-photon polymerization method (2PP) to shape 50µm soft actuators from a thermo-responsive polymer (pNIPAM = poly(N-isopropylacrylamide)). These active cubes demonstrate bending, contraction, twist, or shear deformation in a heated water bath [1]. Their mechanical performances must be characterized statically, to determine the elastic properties (Young modulus, Poisson coefficients) and/or dynamically, to determine the viscoelastic properties.
Objective: The aim of this thesis is to develop a setup to measure the force-displacement character-istics of such actuators. Inspired by Micro-Electro-Mechanical Systems (MEMS) force sen-sors [2] and/or atomic force microscopy (AFM) [3], this set-up will be fabricated in using glass microstructures (to be produced with the FemtoPrint machine) or with other materi-als deemed relevant by the candidate.
Methods: Literature review on characterizing the mechanical performance of soft material at microscale. Design the set-up considering the following criteria: 1) samples are character-ized in water to allow them to swell and shrink, 2) a heating system (conventional or laser) will be used to drive the actuators, and 3) the sensor must be in contact with small samples (50 to 200 µm). Eventually, the results obtained may be supplemented and compared with data obtained with an environmental AFM, at UMons, and/or a nanoindentation system [4], at EMPA (Thun, Switzerland).
Prerequisites: Mechanics (to determine the device shape and develop the different part of the set-up using CAD software), coding (to automatically control the setup), and materials (to un-derstand the material model obtained from experimental measurements).

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	2

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive robotic grippers for fruit harvesting

Description

1) Objectives of the project

Soft robotic grippers have shown strong potential in agricultural harvesting due to their inherent adaptability and gentle interaction with delicate objects. A common approach is the use of suction cups to pick fruits directly from branches. However, conventional suction-based grippers require precise alignment and orientation to form a proper seal, which limits their robustness in unstructured environments.

To address this limitation, we have developed self-closing suction cups and universal vacuum grippers that can conformably grasp objects with varying shapes, sizes, and quantities, without requiring precise alignment. These technologies introduce embodied intelligence at the hardware level, enabling more robust and versatile grasping.

The main challenge in applying these systems to fruit harvesting lies in the limited actuation force of current vacuum-driven bending actuators, which is often insufficient to reliably detach fruits from branches.

This project aims to develop high-force, flexible vacuum actuators and integrate them with self-closing suction cups to create adaptive robotic grippers for fruit harvesting. By combining vacuum actuation with cable-driven mechanisms, the gripper will achieve stronger and more controllable bending. The final goal is to develop an efficient, adaptable gripper capable of handling a wide variety of fruits in realistic harvesting scenarios.

2) Methodology

This project focuses on enhancing actuation force and integrating multiple actuation principles into a single gripper system. The main steps include:

i) Literature study on vacuum actuators and cable-driven soft actuators.
ii) Design and numerical analysis of high-force vacuum bending actuators, including pleated or structured geometries to increase effective pressure area.
iii) Integration of cable-driven mechanisms with vacuum actuation to enhance force output

and controllability.
iv) Fabrication of prototypes using molding or additive manufacturing, such as FFF and SLA 3D printing.
v) Experimental characterization and demonstration of fruit gripping and detachment performance.

To support this project, we already have working prototypes of vacuum actuators and self-closing suction cups that can be further developed. The student will benefit from a research team with strong expertise in soft robotics, as well as collaboration with the FYSC group at VUB for materials and fabrication.

3) the prerequisites needed to succeed in this project

We are looking for students with interests in:

i) CAD design and mechanical design
ii) 3D printing and prototyping
iii) Basic electronics and Arduino
iv) Hands-on experimentation and robotics

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRCNE, M-IRELE
Nombre de sujets	1

Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Comparative study of physics-enhanced graph neural network approaches for multiple degrees-of-freedom system response estimation

Description

- Context of the master thesis

Wind turbines are the biggest dynamic, mass-produced, man-made structures. Their structural response to environmental and operational variations is highly complex and non-linear. As such, both physical modelling and data-driven inference have difficulties in accurately estimating the response. The former require simplifications which, along with unknown quantities (e.g. blade geometry), undermine accuracy. The latter may achieve high performance, but are limited to their training space, and extrapolation isn’t trustworthy. This is also the case for virtual sensing, where limited instrumentation limits the ability to capture the full dynamics of the system, leading to uncertain predictions at unsensed locations, especially outside observed operational conditions.

In this context, physics-enhanced or hybrid modelling has come to the foreground. The philosophy behind it is straightforward: data-driven algorithms have problem-specific physical knowledge embedded into their architectures (loss function, differentiable equations, etc.) which improve generalization and performance. In this thesis, a comparative study of different approaches into embedding physical knowledge into a data-driven algorithm will be research by analyzing performance over multiple degrees-of-freedom systems (MDOF). These (MDOF), represent idealized reductions of real-world structures (e.g. wind turbines, bridges, etc.) and are extremely convenient, as they have low computational costs and their parametrization enables varied response simulation. The baseline algorithm will be a graph neural network.

- References

§ Haywood-Alexander, Marcus, et al. "Discussing the spectrum of physics-enhanced machine learning: a survey on structural mechanics applications." Data-Centric Engineering 5 (2024): e30.
§ Cicirello, Alice. "Physics-Enhanced Machine Learning: a position paper for dynamical

systems investigations." Journal of Physics: Conference Series. Vol. 2909. No. 1. IOP Publishing, 2024.
§ Mehrjoo, Azin, Eleonora M. Tronci, and Babak Moaveni. "A Physics-Informed Framework for Input Load Estimation in Offshore Wind Turbines." International Conference on Experimental Vibration Analysis for Civil Engineering Structures. Cham: Springer Nature Switzerland, 2025.

- Objectives

§ Review virtual sensing in offshore wind turbines.
§ Identify and review physics-enhanced/hybrid modelling approaches.
§ Generate MDOF systems with varying numbers of degrees and exciting load [both intensity and location] in a Python script.
§ Encode MDOF as a graph, including stiffness, damping and mass matrices.
§ Implement a Graph Neural Network (GNN) virtual senser baseline in Python.
§ Assess and compare the addition of physics knowledge into the baseline with relation to: performance over unseen numbers of nodes [extrapolation and interpolation] and unseen excitations [intensity and location].

- Prerequisites/special skills
· Basic python programming.
· Knowledge of fundamentals of structural mechanics (e.g. equations of motion, etc.).
· Attendance of Prof. Deraemaker's Dynamics of Structures or Mechanical Vibrations course (https://structuraldynamics.ulb.be/dynamics-of-structures-2025-2026/)

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Geometric and structural design of flexible joints for deployable scissor grids

Description

Note: if interested, come and discuss the topics with us, to refine the research question based on your skills and interests.

Context:

Deployable structures are fascinating structural mechanisms: they have the ability to transform themselves from a small, closed or stowed configuration to a much larger, open or deployed configuration. Mobile deployable structures have the great advantage of speed and ease of erection and dismantling compared to conventional building forms. They have a wide field of application, from space antennas to festival structures, to adaptable furniture and toys.

At VUB there is 20 years of expertise on these fascinating systems and recently a spin-off company called KONLIGO was created to design and build zero-waste event structures based on our scissor technology.

Because these deployable structures can be used and reused over and over again they are well-suited to support the transition to a zero-waste event industry, where currently the waste problem is huge. Because of the modular construction and high component uniformity, and easy repair and maintenance, they are well-suited for a 'circular business model'.

Topic:
Many new shapes have been developed by us in recent years. Digital models have been made, new shapes have been patented and small-scale models have been realised to test these concepts.
But every new shape has its specific detailing issues to be solved: e new joint that allows the required movement, a new material for the joint or the beams, a modular design that allows reconfiguration, adding stiffening cables or not, etc...

To be able to build our vast library of new and promising shapes for scissor structures, one

possible strategy is to develop new joints that are flexible in one direction and stiff in the other. This requires 3D-printing/prototyping and some material engineering. This could potentially unlock very interesting new shapes for expanding the application potential of scissor grids.
Depending on the interest and the profile of the student(s) involved, different accents/directions can be identified, collaboration between students with a different profile is also accepted:
• Emphasis on the exploration of various configurations based on a range of design criteria and application contexts, through scale models and 2D-3D prototyping
• Parametric modelling of scissor geometry in Rhino/Grasshopper and 3D-models/rendered images
• Prototyping a scissor structure at full scale
The aim of this project is the successful experimental exploration and realisation of deployable scissor structures, based on realistic design criteria. Digital and physical design and fabrication tools can be explored and used for the successful realisation of these new shapes.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRARE, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	2

Supervision

Supervisor : Roels Ellen (ellen.roels@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Universal vacuum gripper with self-closing suction cups for handling thin elastic films

Description

1) The objectives of the project

Vacuum grippers are widely used in manufacturing and logistics due to their compactness, reliability, and high gripping force. In many industrial applications, arrays of suction cups are used to handle objects of varying sizes and shapes. However, when some suction cups are not sealed, vacuum leakage occurs, reducing gripping efficiency and increasing energy consumption.

To address this challenge, our group has developed an advanced self-closing suction cup technology. These suction cups can automatically close when they are not in contact with an object, preventing air leakage and maintaining stable vacuum pressure. This technology introduces embodied intelligence into the hardware level, reducing the need for complex control systems. Based on this concept, we have developed universal vacuum grippers that can handle objects with different shapes and sizes, and these systems have already been tested in industrial environments.

A new challenge arises in the handling of thin elastic film objects, such as plastic bags, packaging films, and flexible sheets. These materials are widely used in logistics, food packaging, recycling, and pharmaceutical industries. However, thin films are difficult to grasp because they deform easily, wrinkle, and may allow air leakage between the suction cup and the surface. Conventional suction cups often fail to reliably pick up such flexible materials.

In this project, we will further adapt our self-closing suction cup and universal gripper technologies to handle thin elastic film objects. The goal is to design and develop a specialized vacuum gripper capable of reliably picking and placing thin film materials commonly found in industrial and logistics applications.

2) Methodology

This project focuses on adapting suction cup multi-material structures, airflow, and self-

closing conditions to improve the gripping reliability of thin elastic films. To achieve these goals, the project will include:

(i) A literature study on vacuum gripping of flexible materials and thin films.
(ii) Design optimization of self-closing suction cups and gripper configurations for handling thin elastic films.
(iii) Manufacturing of prototypes using molding or additive manufacturing methods such as FFF 3D printing.
(iv) Experimental evaluation of gripping reliability, deformation behavior of thin films, and performance comparison with conventional suction cups.

To support this project, we already have working prototypes of self-closing suction cups and universal vacuum grippers. The student will build upon these existing technologies and benefit from the experience of our research team working on soft robotics, vacuum systems, and industrial grippers.

3) Prerequisites needed to succeed in this project

We are looking for students who have interests in:

(i) CAD design and mechanical design
(ii) 3D printing or prototyping
(iii) Basic knowledge of mechanics
(iv) Experimental testing and hands-on engineering
(v) Robotics, automation, or industrial applications

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRELE, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

3D printing of deployable scissor joints

Description

Note: if interested, come and discuss the topics with us, to refine the research question based on your skills and interests.

Context:

Deployable structures are fascinating structural mechanisms: they have the ability to transform themselves from a small, closed or stowed configuration to a much larger, open or deployed configuration. Mobile deployable structures have the great advantage of speed and ease of erection and dismantling compared to conventional building forms. They have a wide field of application, from space antennas to festival structures, to adaptable furniture and toys.

At VUB there is 20 years of expertise on these fascinating systems and recently a spin-off company called KONLIGO was created to design and build zero-waste event structures based on our scissor technology.

Because these deployable structures can be used and reused over and over again they are well-suited to support the transition to a zero-waste event industry, where currently the waste problem is huge. Because of the modular construction and high component uniformity, and easy repair and maintenance, they are well-suited for a 'circular business model'.

Topic:
The deployable bars of a scissor structure are connected by specifically designed joints, that allow the necessary movement. However, there is a specific class of structures that is left out because of the deployment is not possible, or difficult. Unless the joints are designed in such a way that they accommodate this special requirement movement. The projected outcome is an overview of the possibilities for innovative joints for deployable scissor structures that open up the possibilities for new shapes that have never been built before. Physical models (small and medium scale), digital parametric modelling, digital fabrication and potential full-scale testing belong to the possibilities, depending on the chosen focus.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRARE, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	2

Supervision

Supervisor : Roels Ellen (ellen.roels@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Instrumented glass gripper: Percipio Robotics' Tulip gripper revisited (+ internship – to be confirmed by the company Percipio Robotics)

Description

Context: Percipio Robotics is a spin-off from the FEMTO-ST research institute, which has designed the Tulip gripper [1]. This compact, lightweight gripper, weighing less than 30g, is designed for micromanipulation and can grip objects from 50µm to 10mm. It solves the problems of large grippers and fragility frequently encountered in micro-robotics. Parallely, the TIPs department designs and manufactures compliant mechanisms in glass (FemtoPRINT technique), whose deformation is measured with optical/photonics techniques.
Objectives: This thesis aims to design and develop an instrumented version of the Percipio Robotics' Tulip gripper. The master thesis can be preceded by a 3 months internship in the company (Besançon, France).
Methods: Literature review. Functional analysis and requirements. Design. Fabrication and characterization of the flexure mechanism.
Prerequisites: mechanical design, good command of French

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRCNE, M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IRPH
Nombre de sujets	2

Supervision

Supervisor : LAMBERT Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive airflow-based robotic gripper for delicate raspberry harvesting

Description

1) Objectives of the project

Raspberry harvesting is a labor-intensive and costly process because high-quality raspberries must typically be harvested manually to avoid damage. While vibration-based harvesting machines are used in fields, they are not suitable for delicate fruits such as fully matured raspberries for eating. As a result, soft robotic grippers have been increasingly explored as an alternative for automated harvesting. However, most existing soft grippers rely on direct contact forces to grasp the fruit, which still introduces the risk of bruising or damaging these highly fragile fruits.

An even gentler method than mechanical contact is the use of fluidic forces, where airflow can be used to drag the fruit without applying significant mechanical pressure. This approach has strong potential for delicate fruit harvesting. However, several key challenges remain. First, high suction flow rates are often required to generate sufficient lifting force, leading to poor energy efficiency. Second, once the fruit is lifted, an adaptive structure is needed to securely hold and stabilize the raspberry without damaging it.

In our previous research, we developed origami-inspired elastomer actuators that can be fabricated using elastomer 3D printing or molding. These structures allow programmable shape change. Building on this technology, this project aims to design an adaptive orifice structure with a tunable diameter, inspired by origami mechanisms, to efficiently control suction airflow and gently capture raspberries. Such a system has strong potential to address challenges in the rapidly growing agricultural robotics sector, particularly within the raspberry market valued at approximately €3 billion.

The final goal is to develop a prototype suction-based adaptive gripper capable of gently picking raspberries energy-efficiently and improving reliability.

2) Methodology

This project focuses on designing adaptive airflow structures that combine fluidic suction and compliant mechanical response. The project will include:

i) Literature study on robotic harvesting of delicate fruits and suction-based gripping technologies.
ii) Design of origami-inspired tunable orifice structures capable of dynamically adjusting opening diameter.
iii) Fabrication of prototypes using elastomer 3D printing or molding techniques.
iv) Integration of suction airflow systems with the adaptive orifice structure.
v) Experimental evaluation of airflow efficiency, fruit handling stability, and damage reduction performance using the raspberry.

To support this project, we already have experience with origami-inspired elastomer actuators and elastomer fabrication methods. The student will build upon these existing technologies and contribute to developing next-generation agricultural robotic solutions.

3) The prerequisites needed to succeed in this project

We are looking for students who have interests in:

i) CAD design and mechanical design
ii) 3D printing or molding of soft materials
iii) Basic knowledge of mechanics
iv) Hands-on prototyping and experimental testing
v) Interest in robotics, agriculture, or bio-inspired design

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE
Nombre de sujets	1

Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Multi-robot localisation

Description

This thesis topic is a broad collection of subtasks that can be undertaken within multi-robot localisation research.
This includes topics such as:
- Multi-agent SLAM.
- UWB Anchored localisaiton
- Relative pose estimation
- Map sharing
- ODometry sensors: IMU, Camera, VIO, LiDAR, LIO.

And this on multiple different robots:
- AGVs
- Humanoids
- Drones.

In case you want to discuss possibilities in this research field please contact yuri.durodie@vub.be for more details.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	5

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

🤖 Building the Safety Intelligence Layer for Physical AI: A Multi-Disciplinary Robotics Challenge (In partnership with coera — 5 positions available) 🤖

Description

Robots are leaving their cages. But the world they're entering wasn't designed for them — it was designed for us. What's missing isn't better robots. It's a layer of intelligence that doesn't exist yet.

This project, in collaboration with coera, tackles that challenge across five interconnected research tracks — from how a robot perceives and interprets the unpredictable humans around it, to how it decides, reacts, and physically interacts with the world. You'll work on real-time perception, sensor fusion, adaptive control, compliant mechanism design, or structural optimization — each a piece of a larger puzzle that very few teams in the world are trying to solve.

If you're looking for a thesis that sits at the intersection of mechanical engineering, AI, and something that will actually reshape how robots enter society — this is it.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE
Nombre de sujets	5

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Civil Engineering
Master Thesis Topics (M-IRCNE)

Academic year 2026–2027

Investigation of the Micro-Profiling Effect on the Mechanical Behaviour of Thin Steel Sheeting

Program : Civil engineering - M-IRCNE

Description

Cold-formed steel sheeting is widely used in lightweight construction systems such as roofs, floors, and composite decks. In addition to the primary corrugation geometry that provides global bending stiffness, manufacturers increasingly introduce micro-profiling (small-scale surface indentations or ribs) in the flanges of the sheeting (Figure 1). These micro-profiles are intended to improve local stability (delay local buckling), and increase stiffness without significantly increasing material usage [1,2]. Composite slabs are outside the scope of this thesis; consequently, indentations related to composite action are not considered.

Two representative industrial products illustrate this concept:

Figure 1: JI 106-250-750 (Joris Ide) left and – T130M-75L-930 (Ruukki) (right) featuring light micro-profiling on the top flange, and on both top and bottom flanges, respectively.

While the global structural behaviour of profiled steel sheeting is well documented, the mechanical contribution of micro-profiling remains insufficiently quantified. Initiation and development of local buckling modes in the compressed flanges under bending loading will be studied in this thesis at the small scale.

This thesis is embedded in a broader research framework studying acoustic roof decking as sustainable and environmental friendly solution with light weight and low end-of-life impacts. In this thesis, detailed FE models of micro-profiled, small-scale panels will be developed and used for a parametric study allowing a direct comparison between micro-profiling effects for different micro-profile geometries. To ensure reliability, the developed numerical models will be experimentally validated through compression tests on small-scale panels incorporating micro-profiling.

Research Objectives

To quantify and understand the mechanical influence of micro-profiling on thin cold-formed steel sheeting through validated finite element modelling.

1

Geometrical Characterisation and Performance

o

Digitally reconstruct representative micro-profiling geometries of selected sheeting types.

o

Develop parametrised small-scale panel models incorporating realistic micro-profile details. Systematically vary:

▪

Depth,

▪

Spacing,

▪

Shape,…

o

Quantify using finite element modelling the influence on:

▪

Bending stiffness,

▪

Elastic buckling resistance,

▪

Load redistribution mechanisms.

2

Experimental Validation

Manufacture or obtain small-scale micro-profiled panels.

Conduct controlled compression tests.

Measure:

Load–displacement response,

Buckling modes,

Strain development.

3

Validation

Calibrate and validate FE models against experimental results.

Summarize insights.

References

[1] R. Studziński, Z. Pozorski, A. Garstecki (2015). Structural behavior of sandwich panels with asymmetrical boundary conditions. Journal of Constructional Steel Research 104: 227–234

[2] X. Ma, J.W. Butterworth, G.C. Clifton (2008). Unilateral contact buckling of lightly profiled skin sheets under compressive or shearing loads. International Journal of Solids and Structures, 45: 840–849

Objectives of the master thesis

This research is expected to:

•

Give a well-structured comprehensive overview of the state of the art.

•

Provide a mechanistic understanding of how micro-profiling modifies elastic stress fields in thin steel sheeting.

•

Establish validated finite element modelling strategies for small-scale micro-structured panels.

•

Clarify the relative structural efficiency of micro-profiling compared to flat panels.

•

Deliver quantitative design-oriented insights for manufacturers aiming to optimise sheet geometry without increasing material thickness.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IRCNE, M-IREMR-A, M-IREMR-M
Number of topics	1

Supervision

Supervisor : Lincy Pyl

Contact : Lincy.Pyl@vub.be

Mesoscale computational model of continuously reinforced fused filament fabrication

Program : Civil engineering - M-IRCNE

Description

The goal of this master's thesis is to achieve a thorough understanding of the influence of reinforcements on mesoscale stress concentrations. To this end, the addition of geometric features representing reinforcing fiber tows to the geometries presented in [2] is envisioned.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IREMR-A, M-IREMR-M, M-IREMR-O
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Lien : https://www.dropbox.com/scl/fi/msblyv5m3dqndp1hefkab/PBerke-Mesoscale-computational-model-for-FFF-2026-27.pdf?rlkey=63up9euuryhx0mucchczi4wgo&st=zvgubgle&dl=0

Mechanical characterization of non-linear materials to be used as miniaturized actuators

Program : Civil engineering - M-IRCNE

Description

Context: Active soft matter can be used as an actuator in microrobotics. It can deform under an external stimulus such as light, heat, or pH to generate a mechanical output (force and dis-placement). At the microscale, these smart materials can be 3D printed without assembly. In the lab, we use the two-photon polymerization method (2PP) to shape 50µm soft actua-tors out of a thermo-responsive polymer (pNipam = poly(N-isopropylacrylamide)). These active cubes demonstrate bending, contraction, twist, or shear deformation in a heated wa-ter bath [1]. Their mechanical performances such as Young modulus, force-displacement characteristics, or response time must now be characterized.
Objective: The aim of this thesis is to use a setup to measure the force-displacement characteristics of such actuators and to analyze the indentation data with the help of a finite element ap-proach to decouple the elastic parameters (Young modulus, Poisson coefficients) from the visco-elastic parameters.
Methods: Literature review on modeling soft material at microscale. Develop a code to analyze the experimental data. Eventually, the results obtained may be supplemented and compared with data obtained with an environmental AFM, at UMons, and/or a nanoindentation sys-tem [4], at EMPA (Thun, Switzerland).
Prerequisites: Numerical methods

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Number of topics	1

Supervision

Supervisor : Pierre LAMBERT

Contact : pierre.lambert@ulb.be

Co-supervisor: Peter Berke

Contact : peter.berke@ulb.be

Lien : https://plambert.ulb.be/wp-content/uploads/2026/03/2026-03-31_LAMBERT.pdf

Investigation of thermal fields during the manufacturing of 3D printed composites

Program : Civil engineering - M-IRCNE

Description

Context of the master thesis
3D printed composites combine the flexibility of additive manufacturing with the improved mechanical properties of composite materials. An important aspect of the printing process is the thermal field that develops during material deposition, as it directly affects interlayer bonding, residual stresses, and defect formation. Quantifying these thermal fields allows better control of printing parameters and leads to improved print quality and structural performance. A clear understanding of the thermal behavior during printing is therefore essential for improving the reliability of 3D-printed composite components1.
The master's student will employ infrared cameras during the printing of simple structures to capture thermal fields and use them to perform finite element analysis (FEA). This approach facilitates learning the intricacies of the 3D printing process, camera setup, and subsequent data post-processing along with the basics of FEA. The post processing will be achieved in Python using image processing techniques and the FEA in the ABAQUS software. Through this master thesis, the student will gain a holistic understanding of: additive manufacturing (printing process), thermal mechanics (influence of thermal fields), and FEA, equipping them with valuable skills for future endeavors in technology and engineering fields.
Fig. 1 Thermal image during printing.
References
1)
Cattenone, A., Morganti, S., Alaimo, G., & Auricchio, F. (2019). Finite element analysis of additive manufacturing based on fused deposition modeling: Distortions prediction and comparison with experimental data. Journal of Manufacturing Science and Engineering, 141(1), 011010.
Objectives of the master thesis

- Measure transient thermal fields during the 3D-printing process using infrared cameras.
- Process infrared data using Python-based image processing techniques.
- Analyze the influence of printing parameters on the evolution of thermal fields.
- Implement simplified thermal finite element models in Abaqus using experimentally obtained data.
- Assess the implications of thermal fields on the printing process.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRCNE, M-IREMR-A, M-IREMR-M
Number of topics	1

Supervision

Supervisor : Lincy Pyl / Contact : Lincy.Pyl@vub.be

Distortion- and Aberration-free Microlens Array Design for Plenoptic Cameras

Program : Civil engineering - M-IRCNE

Description

Design, simulate, and evaluate a microlens array with minimal distortion and aberrations for use in plenoptic cameras.

Context

Plenoptic cameras consist of a main lens, a microlens array, and a CMOS sensor. These special design captures both the spatial distribution of light in a scene and its angular distribution, thanks to the microlens array. Indeed, each microlens in the array acts like a tiny camera, sampling the scene from a slightly different viewpoint. The resulting image, called a plenoptic image, is a collection of these samplings and it encodes the light distribution of the scene. This means that a single exposure contains rich information that can later be computationally exploited to refocus images, estimate depth, or even synthesize new viewpoints. These capabilities make plenoptic imaging a powerful tool for applications such as 3D reconstruction, microscopy, and computational photography.

The most important component of the camera is the microlens array, whose design determines the balance between spatial and angular resolution, light efficiency, and overall image quality. Parameters such as lens shape, pitch, focal length, optical aberrations, and distortion directly impact how accurately the light field is sampled and reconstructed. Therefore, the design and simulation of microlenses are essential for achieving a high-quality plenoptic camera. A rigorous understanding and optimization of these elements are crucial for advancing its capabilities.

Objective

Develop a microlens array design that minimizes chromatic aberration and image distortion while optimizing light efficiency and image resolution.

The project should provide design analysis and quantitative results for:

* Microlens profile (shape, sag height, ...)
* Geometrical properties (pitch, aperture, arrangement, ...)
* Optical properties (focal length, depth of field, spot size, Strehl ratio, ...)
* Image resolution, aberration and distortion tests
* (and additional relevant metrics)

Takeaways

By the end of this project, students will:

1. Understand working principles of a plenoptic camera;
2. Model an optical component using standard optical design software;
3. Analyze how microlens array parameters affect imaging performance;
4. Apply computer vision techniques to analyze and evaluate imaging systems in Python or C++;

5. Doing a complete engineering pipeline: research -> modeling -> simulation -> evaluation -> iterate;

Prerequisite

* Programming skills in Python and/or C++
* Basic knowledge of CAD and geometrical optics is recommended (not mandatory)
* Experience with Zemax (not mandatory)

Supervision

Supervisors: Daniele Bonatto, Brenno Ferreira

Contact Person: Brenno Ferreira (brenno.ferreira.ribeiro@ulb.be)

Language	**EN (english)**
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Daniele Bonatto

Contact : daniele.bonatto@ulb.be

Computational analysis of the dynamic transformation behavior of bistable scissor structures

Program : Civil engineering - M-IRCNE

Description

This work consist of (i) understanding the concept and challenges of bistable scissor structures and a literature review on modeling efforts of their dynamic behavior, (ii) set up of 3D FEM models in a commercial FE software, (iii) investigating their dynamic deployment including the proposal of damping solutions, using appropriate loads and boundary conditions, (iv) proposing a design strategy that incorporates notions of the dynamic behavior of BDS.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IREMR-A, M-IREMR-M, M-IREMR-O
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Co-supervisor: Murillo Santana

Lien : https://www.dropbox.com/scl/fi/aw8udqwus7px25arwai2l/PBerke-BDS-dynamic-transformation-2026-27.pdf?rlkey=hhbjruc8uof6df9x3h83798ac&st=39bgtdrw&dl=0

Experimental mid-scale implementation of Enzyme-Induced Carbonate Precipitation (EICP): from setup to testing prospects

Program : Civil engineering - M-IRCNE

Description

Enzymatic induced calcite precipitation (EICP) is a stabilization technique that has recently gained prominence among geotechnical engineers and practitioners. EICP exploits the action of the urease enzyme to catalyze the hydrolysis of urea and to produce carbonate ions, which then react with calcium ions inside the pore water to cause precipitation of calcium carbonate (i.e. calcite). The precipitated mineral bonds particles together, thus reducing water permeability and improving the mechanical characteristics of the soil. Despite promising results, the implementation of EICP technology at the field scale is still in its early stages stage with only a few published research on the application of EICP beyond the smaller material scale and with no clear procedure or standards. Despite simply injecting EICP stabilizing solution (made of urease, urea and calcium chloride) into the ground may be an option, the homogeneity of EICP treatment depends on many factors such as the type of soil, the specific urease enzyme source used, the site conditions, etc. Compared to current stabilization and grouting technologies, the advantages of EICP would be: no spoil materials, multiple cycles of treatment could be applied if necessary, due to the low viscosity of the solution low injection pressures could be used, reduction of energy use and equipment size, as a biobased cementation process the cradle-to-grave environmental impacts may be reduced. The factors influencing the commercial adoption of Enzymatic Induced Calcite Precipitation (EICP) at the field scale, as compared to currently prevalent methods in the market, such as lime stabilization and jet grouting, primarily revolve around cost considerations and a noticeable knowledge gap. These elements play pivotal roles in shaping the decision-making process, highlighting the need for further understanding and awareness as key drivers for the integration of EICP technology within the industry. “How to implement a cementing solution made of crude urease enzyme extract, urea and calcium chloride in the field for geotechnical applications?” is the research question behind the present experimental work. This research builds upon and will continue ongoing Master's thesis already in place at the Geomechanics laboratory. “How to implement a cementing solution made of crude urease enzyme extract, urea and calcium chloride in
the field for geotechnical applications?” is the research question behind the present experimental work. This research builds upon and will continue ongoing Master's thesis already in place at the Geomechanics laboratory. “How to implement a cementing solution made of crude urease enzyme extract, urea and calcium chloride in the field for geotechnical applications?” is the research question behind the present experimental work. This research builds upon and will continue ongoing Master's thesis already in place at the Geomechanics laboratory. Technical aspects - The thesis will exploit a relatively low-cost and simple stabilization technology (EICP) that makes use of crude urease enzyme extracted from soybeans. Two methods of urease extraction are explored: soybeans are either centrifuged into a juice or crushed into a fine powder. Throughout this thesis, bench tests will involve mid-scale boxes or tanks filled with stabilized fine-grained soil. The experimental work will be based on the results of the recent research study (MARIE FOELIEX’s Master Thesis-Academic year 2024-2025) and will include the setup of the equipment for stabilization, choice of the best protocol for optimized stabilization, mechanical testing of samples extracted from the mid-scale model to evaluate the in situ strength improvement, monitoring of the stabilization process with selected sensors and analytical testing of the stabilized soil to evaluate the extent of treatment, carbonate content, etc.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Alessia Cuccurullo

Contact : alessia.cuccurullo@ulb.be

3D finite element modeling of the robustness of reinforced concrete structures

Program : Civil engineering - M-IRCNE

Description

The envisioned work consists in: (i) a literature review of existing experimental and numerical works treating a 3D for structural robustness of RC frames, (ii) getting familiar with the use and limitations of OpenSees/Salome-meca, (iii) setting up FE models that allow reproducing experimental results from the literature, (iv) performing the 3D FE study of a large RC structure and a critical comparison of the predictions from 2D and 3D models.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Lien : https://www.dropbox.com/scl/fi/dtnxer0ufcbw3j7u5kimo/PBerke-3D-robustness-2026-27.pdf?rlkey=56btndel9vyauy2tog3uaeoeu&st=ony1mpm6&dl=0

Impact of vertical boreholes deviation on the performance of geothermal borefields

Program : Civil engineering - M-IRCNE

Description

Geothermal energy is a renewable source of energy, based on the extraction of heat from the Earth for heating or energy production. Amongst the different types of geothermal systems, borehole heat exchangers (BHEs), coupled with a ground source heat pump (GSHP) at the ground surface, are the most common technique to extract thermal energy from the subsurface. The standard BHE is a closed loop U-pipe system, where a circulating heat carrier fluid is heated or cooled by the surrounding grout and ground. After the drilling of a vertical borehole, closed loop U-pipes are introduced within the borehole. The borehole and pipes are then grouted using a sealant that offers good thermal properties to minimize the loop field's thermal resistance and maximize the exchange of heat between the ground and the heat transfer fluid.

The design of such systems relies on the knowledge of the thermal properties of the ground (i.e. thermal conductivity, specific heat capacity, initial temperature), the energy demand from the building and the geometry of the bore field (e.g. boreholes spacing, depth of boreholes, etc.). The design must demonstrate, through the modelling of the heat transfers between the ground and the BHEs, the long-term sustainability of the energy resource (i.e. ground heat extraction during winter is compensated by natural replenishment or heat injection during summer). Nowadays the design approaches always assume vertical boreholes. However, measurements of inclination on a series of boreholes of the multi BHEs field at USquare (Brussels) have shown the large deviation of the boreholes from the vertical axis (Figure 1), which can impact the thermal interferences between BHEs (i.e. possible heat overextraction in the limited volume of ground located between two nearby boreholes).

Context of the master thesis

Geothermal energy is a renewable source of energy, based on the extraction of heat from the Earth for heating or energy production. Amongst the different types of geothermal systems, borehole heat exchangers (BHEs), coupled with a ground source heat pump (GSHP) at the ground surface, are the most common technique to extract thermal energy from the subsurface. The standard BHE is a closed loop U-pipe system, where a circulating heat carrier fluid is heated or cooled by the surrounding grout and ground. After the drilling of a vertical borehole, closed loop U-pipes are introduced within the borehole. The borehole and pipes are then grouted using a sealant that offers good thermal properties to minimize the loop field's thermal resistance and maximize the exchange of heat between the ground and the heat transfer fluid.

The design of such systems relies on the knowledge of the thermal properties of the ground (i.e. thermal conductivity, specific heat capacity, initial temperature), the energy demand from the building and the geometry of the bore field (e.g. boreholes spacing, depth of boreholes, etc.). The design must demonstrate, through the modelling of the heat transfers between the ground and the BHEs, the long-term sustainability of the energy resource (i.e. ground heat extraction during winter is compensated by natural replenishment or heat injection during summer). Nowadays the design approaches always assume vertical boreholes. However, measurements of inclination on a series of boreholes of the multi BHEs field at USquare (Brussels) have shown the large deviation of the boreholes from the vertical axis, which can impact the thermal interferences

between BHEs (i.e. possible heat overextraction in the limited volume of ground located between two nearby boreholes).

The aim of the master thesis is to investigate the impact of non-vertical BHE on the design and the sustainability of such geothermal systems. In case of non-sustainable design with standard approaches, adapted design methods will be proposed to better consider the non-verticality of boreholes.
The master thesis will include the following steps:

- Analysis of deviation measurements on boreholes at USquare
- Literature review on deviation for BHEs and design methods of bore field
- Design of bore field with standard approaches considering vertical boreholes (EED software, ULB analytical model)
- Adaptation of the ULB analytical model to consider non-vertical boreholes
- Design of bore field with adapted analytical model and non-vertical boreholes (with random/stochastic orientation or geological-dependent orientation) and comparison with standard approaches
- Development of new design methods considering the bore path uncertainty (if needed)

References

Shen J., Luo Y., Zhou C., Song Y., Tian Z., Fan J., Zhang L., Liu A. (2025) A slightly inclined deep borehole heat exchangers array behaves better than vertical installation. Renewable Energy. 238, 121963.
Cui P., Yang H., Fang Z. (2006) Heat transfer analysis of ground heat exchangers with inclined boreholes, Applied Thermal Engineering. 26, 1169–1175
Steinbach P., Schulte D.O., Welsch B., Sass I., Lang J. (2021) Quantification of bore path uncertainty in borehole heat exchanger arrays using adaptive anisotropic stochastic collocation. Geothermics. 97, 102194.

Language	**EN (english)**
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Pierre Gerard

Contact : gerard.pierre@ulb.be

Hybrid Bio-Cemented Earthen Materials Using Enzyme-Induced Carbonate Precipitation (EICP) and Polysaccharide Biopolymers (Xanthan Gum and Guar Gum)

Program : Civil engineering - M-IRCNE

Description

The production of conventional construction materials such as fired clay bricks and cement-bound blocks is energy-intensive and remains a significant contributor to global CO_2 emissions. This has motivated increasing interest in alternative low-carbon stabilization strategies capable of reducing embodied energy while maintaining structural performance. Among bio-based approaches, two techniques have emerged as particularly promising: biopolymer treatment (BPT) and enzyme-induced carbonate precipitation (EICP). Although both methods enhance soil strength through fundamentally different mechanisms, their combined potential remains insufficiently understood. Biopolymer treatment involves the incorporation of natural polysaccharides such as xanthan gum and guar gum into soil. These long-chain macromolecules dissolve in water and form hydrogel networks through hydrogen bonding, chain entanglement and, in some cases, ionic crosslinking. In granular soils, the resulting viscous hydrogel phase increases interparticle adhesion and creates flexible polymer bridges capable of accommodating strain. In fine-grained soils, polymer chains adsorb onto clay mineral surfaces through electrostatic interactions and hydrogen bonding, modifying the diffuse double layer and promoting aggregate formation. The stabilization mechanism is therefore not purely cementitious, but viscoelastic in nature, often leading to improved tensile resistance and enhanced ductility. However, the mechanical contribution of biopolymers is strongly dependent on moisture content, and significant reductions in stiffness and strength can occur under wetting-drying cycles due to hydrogel swelling and contraction. In contrast, EICP is a biomineralization process in which urease catalyzes the hydrolysis of urea, producing carbonate ions that react with calcium ions to precipitate calcium carbonate ($CaCO_3$). The precipitated crystals form rigid interparticle bridges that increase contact stiffness and compressive strength. EICP has been investigated for soil improvement, crack remediation in cementitious materials, erosion control, soil reinforcement and additive manufacturing of bio-cemented products. Nevertheless, its application in the production of bio-bricks remains limited, partly due to lower calcium conversion efficiency compared with microbially induced carbonate precipitation, and partly due to the tendency of carbonate precipitation to be spatially heterogeneous when used as a standalone treatment. Recent observations indicate that xanthan gum can enhance retention of carbonate precipitates produced by EICP, improving resistance to erosion and mechanical degradation. This suggests that biopolymers may not only contribute mechanically through hydrogel bonding, but may also influence reaction-transport processes by modifying ion mobility, solution viscosity and nucleation sites. The scientific question is therefore not simply whether strength increases when the two methods are combined, but whether a true composite bonding system can be engineered at the microstructural scale. The working hypothesis of this thesis is that combining EICP with xanthan gum and guar gum produces a coupled bio-mineral network in which flexible hydrogel bridges coexist with rigid $CaCO_3$ crystals. In such a system, the polymer phase may regulate ion transport and precipitation morphology, while the mineral phase provides stiffness and compressive capacity. The resulting microstructure may exhibit improved bond continuity, reduced brittleness and enhanced durability compared with single-mechanism stabilization. Understanding this interaction requires a deeper investigation linking polymer physics,

carbonate precipitation kinetics and macroscopic mechanical response.
The main objective of this thesis is to evaluate whether a hybrid stabilization strategy combining enzyme-induced carbonate precipitation (EICP) with natural biopolymers such as xanthan gum and guar gum can produce mechanically efficient and durable bio-cemented earthen materials suitable for low-carbon
construction applications.
The study aims to determine how polymer type and concentration influence carbonate precipitation efficiency, crystal morphology and spatial distribution, and whether the presence of a hydrogel network enhances the uniformity and retention of $CaCO_3$ within the soil matrix. The mechanical performance of the hybrid system will be assessed through unconfined compressive strength tests and three-point bending tests in order to characterize both compressive capacity and flexural behaviour. Particular attention will be given to stress-strain response, post-peak softening and ductility in order to evaluate whether the addition of biopolymers mitigates the brittle behaviour typically associated with EICP only treatment. The results will be compared with EICP-only. Durability will be evaluated through water absorption measurements, initial rate of absorption tests, and cyclic wetting-drying and freeze-thaw exposure, in order to assess moisture sensitivity and degradation mechanisms. Where relevant, thermal conductivity may also be measured to examine the potential of the hybrid material for earthen construction applications. The expected outcome is a deeper understanding of how polymer-mineral interactions influence composite bonding, mechanical response and environmental resistance, and whether this hybrid system can offer a viable and more resilient alternative to conventional cement-bound materials.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IRARE
Number of topics	1

Supervision

Supervisor : ALESSIA CUCCURULLO

Contact : alessia.cuccurullo@ulb.be

Incorporating adaptivity in quasi-discrete modeling of the fracture of heterogeneous materials

Program : Civil engineering - M-IRCNE

Description

This work consist of (i) the in-depth understanding of the quasi-discrete (QD) approach, (ii) the application of the quasi-discrete methodology to benchmark problems, (iii) the extension of QD by adaptivity, i.e. the coarsening and refinement of the spatial resolution on the fly.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IREMR-A, M-IREMR-M, M-IREMR-O
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Lien : https://www.dropbox.com/scl/fi/loxeqca60yhrr4rtz83jj/PBerke-Quasi-discrete-adaptivity-2026-27.pdf?rlkey=tbi8h5xmsaa8dmnm94fithrdz&st=9g4zgo0c&dl=0

Computational modeling of the residual stresses generated in the 3D printing process employing continuous fiber reinforced filaments

Program : Civil engineering - M-IRCNE

Description

The objective of this master's thesis is a thorough understanding and the development of a FEM-based workflow to generate thermal histories and a good estimate of residual stresses in FDM printed parts, accounting for the thermo-mechanical anisotropy of continuous carbon fiber reinforced filaments. The modeling is envisioned to be done in Abaqus by progressively activating finite elements in the mesh based on the printing path.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IREMR-A, M-IREMR-M, M-IREMR-O
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Co-supervisor: Ferdinando Auricchio

Lien : https://www.dropbox.com/scl/fi/p29relo1a4id8hlhpyngv/PBerke-3D-printing-residual-stress-2026-27.pdf?rlkey=saz2d5azaiuvc57k1dkn8supe&st=bmp4pimr&dl=0

Adaptable Tensor Display

Program : Civil engineering - M-IRCNE

Description

Develop a fully functional prototype of a **configurable tensor display** with a professional finish.
Context

Tensor Display, also called compressive light display, or multi-layer light filed display, are a class of glasses-free 3D displays. They typically consist of stacked LCD layers placed in front of a backlight. While three-layer systems are common, configurations with 2, 3, or 4 layers are also used, and the spacing between layers is an important design parameter.

Objective

Design and build a hardware and software platform for a tensor display that can be easily reconfigured.
The prototype should support:

- Switching between 2, 3, or 4 layers
- Adjusting the spacing between layers
- Software control capable of operating the display under different configurations

The key goals are:

* Building a modular tensor display prototype with interchangeable mechanical components
* Developing the software to operate the display in multiple configurations
* Integrating all elements into a robust, polished prototype

Prerequisite

* Programming skills in C++ and Python
* Basic knowledge of CAD and 3D printing is recommended but not mandatory

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : Daniele Bonatto

Contact person : Eline Soetens (eline.soetens@ulb.be)

Modeling of the 3D printing of concrete using the Particle Finite Element Method

Program : Civil engineering - M-IRCNE

Description

This work consist of (i) the in-depth understanding of the PFEM and of the physics and challenges governing 3D printing of concrete (3DC), (ii) set up of PFEM models of increasing complexity for 3DC, (iii) investigating the influence of model parameters on the final filament geometry.

Language	**EN (english)**
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Lien : https://www.dropbox.com/scl/fi/5mag9vqb4wll9tr8qxzaq/PBerke-Concrete-3D-printing-modeling-2026-27.pdf?rlkey=yfetctxndi5ifxqih2hi0ipai&st=cltchr5j&dl=0

Design optimization of Baubotanik living plant structures

Program : Civil engineering - M-IRCNE

Description

Living plant structures, referred to as Baubotanik structures, are promising sustainable solutions in civil engineering, acting as CO2 sinks, as opposed to the classical constructions that are responsible for a large part of the worldwide CO2 emissions. Such structures have been implemented in the past as experiments and proofs-of-concept, without however following a proper engineering design. The master thesis answers to this gap of knowledge of living plant structures from the perspective of civil engineering design.
This work consists of (i) the understanding of the specificity and challenges related to building with living plant structures, (ii) the mastering of the current design approach based on Abaqus and MatLab coupling that incorporates growth and material models, (iii) the formulation of a multi-objective optimization problem of the design aiming at balancing structural performance and growth duration preceding the exploitation, (iv) the incorporation of uncertainties in the optimum design, (v) the application of the developed design approach to different real life scenarios.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IRARE
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Lien :
https://www.dropbox.com/scl/fi/9uhkufz1vuibk56qyc9mk/2024_Archi_Guillemot.pdf?rlkey=ox98xwj11acs9q5lrhhqu4y26&st=bnce91x0&dl=0

Adaptable Tensor Display

Program : Civil engineering - M-IRCNE

Description

Develop a fully functional prototype of a **configurable tensor display** with a professional finish.
Context

Tensor Display, also called compressive light display, or multi-layer light filed display, are a class of glasses-free 3D displays. They typically consist of stacked LCD layers placed in front of a backlight. While three-layer systems are common, configurations with 2, 3, or 4 layers are also used, and the spacing between layers is an important design parameter.

Objective

Design and build a hardware and software platform for a tensor display that can be easily reconfigured.
The prototype should support:

- Switching between 2, 3, or 4 layers
- Adjusting the spacing between layers
- Software control capable of operating the display under different configurations

The key goals are:

* Building a modular tensor display prototype with interchangeable mechanical components
* Developing the software to operate the display in multiple configurations
* Integrating all elements into a robust, polished prototype

Prerequisite

* Programming skills in C++ and Python
* Basic knowledge of CAD and 3D printing is recommended but not mandatory

Supervision

Supervisors : Daniele Bonatto, Eline Soetens

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : Daniele Bonatto

Contact person : Eline Soetens (eline.soetens@ulb.be)

Linking Atterberg Limits to Material Strength: A Comprehensive Study for Predicting the Shear Strength and Stability of Fine-Grained Soils

Program : Civil engineering - M-IRCNE

Description

In soil mechanics, the Atterberg limits - comprising the Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) - are among the most distinctive and easily measurable properties of fine-grained soils. These limits serve as fundamental indicators of soil consistency, behavior, and workability, providing essential information for soil classification. Since they are influenced by the same physical factors as other mechanical properties, they have long been considered a practical basis for predicting soil behavior. However, despite their widespread use in soil classification, their direct correlation to key mechanical properties, such as shear strength, compressibility, and stability, remains a topic of ongoing research. Numerous studies have explored the relationship between Atterberg limits and soil strength parameters, such as cohesion, friction angle, and shear strength. However, their findings vary significantly due to the complex interactions between soil mineralogy, moisture content, and structure. Fine-grained soils contain different forms of water, including interparticle and interaggregate pore water, as well as adsorbed water on the surfaces of clay minerals. The quantity and distribution of these water phases play a crucial role in determining soil strength, yet traditional interpretations of Atterberg limits often do not fully account for these factors. Additionally, the relationship between the Atterberg limits and mechanical properties is further complicated by the presence of swelling and non-swelling clay minerals, which respond differently to moisture changes and external loads. Ultimately, this study will contribute to a more robust and scientifically grounded approach to using Atterberg limits as a tool for geotechnical engineering and soil behavior assessment. Furthermore, by refining the interpretation of Atterberg limits in the context of unsaturated soil mechanics, this research could expand its applicability in diverse civil engineering projects, such as slope stability analysis, foundation design, and embankment construction. This research aims to explore the influence of Atterberg limits on the shear strength of fine-grained soils, focusing on how variations in LL, PL, and PI affect key strength parameters under different loading conditions. By conducting a comprehensive study that includes laboratory testing, statistical analysis, and model development, the research seeks to establish empirical relationships that can enhance the predictive capabilities of Atterberg limits for soil strength and stability. The laboratory testing will include the experimental measurement of Atterberg limits and the performance of unconfined compression and direct shear tests, but also comparing data from different soil types to assess trends and variability. The study will consider both swelling and non-swelling soils to determine the extent to which Atterberg limits can be reliably used in geotechnical design. The use of regression models or AI-based techniques to enhance predictive capabilities will be evaluated. At last, the research findings will be compared with existing empirical models in soil mechanics literature. The expected outcomes of this research include a deeper understanding of how Atterberg limits influence the mechanical behavior of fine-grained soils and the development of predictive models that link soil consistency to shear strength characteristics.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : ALESSIA CUCCURULLO

Contact : alessia.cuccurullo@ulb.be

Mechanical and Suction-Controlled Behaviour of Biopolymer-Stabilized Soils Using Guar Gum and Xanthan Gum

Program : Civil engineering - M-IRCNE

Description

Biopolymer-based soil stabilization is increasingly explored in geotechnical engineering as a low-carbon alternative or complement to traditional binders. Polysaccharide biopolymers such as xanthan gum and guar gum can significantly modify soil behaviour by forming viscous or gel-like networks within the pore space. These networks create interparticle bridges and increase apparent cohesion, often improving strength and erosion resistance at relatively low dosages. Unlike cementitious binders, however, the stabilizing mechanism is strongly coupled to water: biopolymers swell, soften, and reorganize with changes in moisture content. As a result, the mechanical response is not solely governed by density and cementation, but also by suction, degree of saturation, and the hydro-mechanical path followed during loading and wetting-drying. From an unsaturated soil mechanics viewpoint, this introduces a central scientific issue. In biopolymer-treated soils, suction does not only contribute to effective stress through capillarity; it also controls the state and stiffness of the polymer network itself. Changes in suction may lead to competing effects: increasing suction can enhance capillary bonding and increase stiffness, while simultaneously dehydrating the polymer gel and altering its connectivity. Decreasing suction can reduce capillary effects but trigger gel swelling and potential loss of interparticle bonding continuity. These coupled mechanisms are expected to depend strongly on polymer type. Xanthan gum, which tends to form more rigid and persistent hydrogel structures, may retain bonding better under suction changes, whereas guar gum, which is often more sensitive to hydration state, may exhibit stronger softening upon wetting. The soil type (granular vs clayey), ionic environment, and mixing/cure protocol further influence polymer adsorption, chain entanglement, and the resulting pore-scale architecture. A key limitation of current literature is that many biopolymer studies report strength changes at a few water contents without controlling suction, making it difficult to distinguish true suction effects from uncontrolled hydraulic state and hysteresis. For geotechnical applications where soils experience seasonal suction cycles, infiltration events, or partially saturated service conditions, a suction-controlled framework is needed. This thesis positions biopolymer stabilization within a rigorous hydro-mechanical approach by explicitly controlling suction and tracking the evolution of strength, stiffness, ductility, and volumetric response along defined wetting and drying paths. The main objective of this thesis is to establish a physically grounded understanding of the mechanical behaviour of guar-gum- and xanthan-gum-stabilized soils under controlled suction, and to identify how polymer type and dosage influence strength, stiffness and deformation mechanisms across unsaturated states. The study aims to quantify how suction affects the shear strength parameters and stress-strain response of biopolymer-treated materials, including peak strength, post-peak softening, and ductility. It will investigate whether the biopolymer contribution behaves as a suction-dependent apparent cohesion, a suction-dependent stiffness modification, or a combined mechanism coupled to fabric changes and degree of saturation. Particular attention will be given to hysteresis effects by comparing wetting and drying paths at the same suction level, and to the reproducibility of response after hydraulic cycling. A second objective is to connect macro-scale mechanical outcomes to hydraulic behaviour by determining how biopolymers modify the soil-water retention curve, air-entry value, and permeability evolution, and how these hydraulic changes feed back into suction-controlled strength. The overarching goal is to develop a consistent interpretation framework

suitable for geotechnical design and performance assessment under environmental loading. The experimental campaign will begin with the selection and characterization of a reference soil (or two soils, for example a sand and a clayey silt) to distinguish polymer effects in granular versus fine-grained matrices. Initial characterization will include grain size distribution, Atterberg limits when relevant, specific gravity and compaction characteristics. Biopolymer-treated specimens will then be prepared with controlled polymer dosages for both guar gum and xanthan gum, using consistent mixing energy, water content, curing time, and density targets to ensure comparability. Hydraulic characterization will include measurement of soilwater retention behaviour for untreated and treated soils, allowing identification of shifts in air-entry value and retention capacity induced by each polymer. Triaxial tests will be used to determine shear strength and
stress-strain response at different suctions and confining pressures, with attention to the evolution of failure mechanisms.

Language	**EN (english)**
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Alessia Cuccurullo

Contact : alessia.cuccurullo@ulb.be

EICP Chemo-Mechanical Instability and Localized Carbonate Precipitation

Program : Civil engineering - M-IRCNE

Description

Bio-mediated ground improvement techniques have gained increasing attention in geotechnical engineering as lower-carbon alternatives to conventional cement based stabilization. Among them, Enzyme-Induced Carbonate Precipitation (EICP) is a chemical-biological process in which urease catalyzes the hydrolysis of urea. This reaction produces carbonate ions that react with calcium ions in solution to precipitate calcium carbonate ($CaCO_3$). The simplified reaction sequence involves urea hydrolysis into ammonium and carbonate species, followed by $CaCO_3$ precipitation when sufficient calcium is present. In porous geomaterials, the precipitated calcite crystals form interparticle bridges, increase contact stiffness, and reduce pore connectivity. At the macroscale, this may result in improved compressive strength, increased shear resistance, and reduced permeability. However, a key limitation of EICP in real soils is not whether precipitation occurs, but whether it occurs in a mechanically beneficial and spatially uniform manner. Reaction-transport processes govern the distribution of carbonate formation. Transport of reactants through the pore network depends on local permeability, pore geometry, and flow boundary conditions. As precipitation develops, $CaCO_3$ crystals progressively reduce pore throat sizes and modify hydraulic conductivity. This creates a feedback loop. Precipitation alters permeability and pore geometry, which modifies transport paths and local reaction rates. The modified transport field then further localizes precipitation. This chemo-hydraulic self-organization mechanism can generate strong spatial heterogeneity in carbonate content at both the pore scale and the specimen scale. From a mechanical standpoint, such heterogeneity is not secondary, it is governing. Localized carbonate enrichment produces zones of higher stiffness and bond density embedded within weaker regions. The treated material therefore behaves as a naturally structured composite with spatially varying cementation. Under loading, stress redistributes toward stiffer zones, while strain localizes along stiffness gradients. Shear bands may initiate preferentially at interfaces between densely cemented “stiff islands” and surrounding matrix. Therefore, most existing studies treat precipitation heterogeneity as an experimental inconvenience to be minimized. The fundamental research gap lies in understanding that chemo-mechanical instability is an emergent phenomenon controlled by reaction-transport coupling. A predictive framework requires linking carbonate precipitation patterns to stiffness contrasts, stress redistribution, and failure path development. The central hypothesis of this thesis is that localized carbonate precipitation governs the onset and orientation of strain localization through spatial stiffness gradients, and that reaction-transport feedback is the primary driver of mechanical instability in EICP-treated earthen materials.
The main objective of this thesis is to investigate the coupling between reaction-transport processes and mechanical instability in EICP-treated earthen materials. The study aims to determine how spatial heterogeneity in carbonate precipitation controls stiffness gradients, stress redistribution and strain localization. It will
examine whether localized carbonate enrichment correlates with shear band initiation and failure path orientation. The thesis will also explore whether controlled heterogeneity can be engineered to influence failure mechanisms in a predictable manner, reframing heterogeneity from a limitation to a governing design parameter. The experimental work will begin with controlled EICP treatment of laboratory specimens under different injection or percolation conditions designed to promote varying degrees of reaction-transport coupling. Flow boundary conditions will be adjusted in order to generate distinct precipitation patterns, ranging

from relatively uniform distribution to strongly localized clogging. Spatial distribution of $CaCO_3$ will be quantified through carbonate content mapping along specimen height and, where possible, through microstructural imaging techniques such as scanning electron microscopy. Local variations in stiffness may be
estimated using small-strain measurements or indirect mechanical profiling along the specimen. Mechanical behaviour will be investigated through unconfined compression and triaxial testing, with particular attention to stress-strain response and post-peak localization. If available, digital image correlation will be used to identify strain localization patterns and correlate them with mapped carbonate distribution. The orientation and thickness of shear bands will be analysed relative to precipitation gradients. The results will be interpreted within a chemo-mechanical framework linking precipitation heterogeneity to emergent instability.

Language	**EN (english)**
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

Supervision

Supervisor : Alessia Cuccurullo

Contact : alessia.cuccurullo@ulb.be

Treatment of contact conditions within the isogeometric method, application to complex contact geometries

Program : Civil engineering - M-IRCNE

Description

The main task is the implementation of the contact treatment within the isogeometric framework. This will require: (i) understanding the concepts of the isogeometric method for structural applications in linear elasticity, (ii) a literature review on the available contact formulations (with and without friction), (iii) the implementation and validation of the chosen one and (iv) the application of the resulting non-linear computational tool to a contact problems (e.g. rough surface contact).

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IREMR-A, M-IREMR-M, M-IREMR-O
Number of topics	1

Supervision

Supervisor : Péter Berke

Contact : peter.berke@ulb.be

Lien : https://www.dropbox.com/scl/fi/jlyk29d55hi6hd52ubges/PBerke-Isogeometric-contact-2026-27.pdf?rlkey=6dt2zgahxwgzs37h7k2yden6w&st=p2jqkc8l&dl=0

Hexagonal Fourier transform for Compression of Plenoptic images

Program : Civil engineering - M-IRCNE

Description

Plenoptic cameras (such as Raytrix) possess a main lens, a sheet of micro-lens, and a CMOS sensor. This special design offers the possibility to capture directional light rays and thus, 3D information about the scene. These cameras are called Light field cameras and are theoretically more suitable for 3D and VR applications than conventional cameras. Due to their structure, they capture an image composed of many micro-images placed in a hexagonal grid, creating patterns that are non-optimal to compress using the JPEG algorithm, even if the image itself presents redundancies that are not exploited.
The JPEG algorithm divides the image in blocks then uses the Fourier transform to compute the blocks in the frequency domain. Then, only the most significant frequencies for the human eye are encoded, creating a low-storage representation of the image. To decompress the image, the inverse operation is performed.
Context
The aim of this thesis is to design a compression scheme using a hexagonal lattice for images in plenoptic format, and explore its efficiency. Using block sizes corresponding to the micro-images will simplify the encoding of the hexagonal image structure. Several datasets captured with different plenoptic cameras (in micro-image size, resolution, depth of field) will be tested and compared with the MPEG explorations of lenslet video coding activities.
Objective
At the end of the year, the student must present
An implementation of a hexagonal block-based adaptation of the JPEG compression
Compute its efficiency compared to classical image compression framework with MPEG standards
Prerequisite
C++ / python
Any multimedia course

Contact person
sarah.dury@ulb.be, daniele.bonatto@ulb.be
References
Hexagonal image processing :
L. Middleton et J. Sivaswamy, Hexagonal image processing: a practical approach, Springer. in Advances in pattern recognition, no. Advances in pattern recognition. London: Springer, 2005.
Plenoptic camera :
C. Perwass et L. Wietzke, Single lens 3D-camera with extended depth-of-field, IS&T/SPIE Electronic Imaging, Burlingame, California, USA, 2012, p. 829108. doi: 10.1117/12.909882.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : Daniele Bonatto

Contact person
sarah.dury@ulb.be, daniele.bonatto@ulb.be

Hybrid Chemo-Bio Stabilization of Fine-Grained Soils: Reducing Lime Content through Enzyme-Induced Carbonate Precipitation (EICP)

Program : Civil engineering - M-IRCNE

Description

Lime stabilization is one of the most established and reliable techniques in geotechnical engineering for improving soft and fine-grained soils. It is extensively used in subgrade stabilization, embankment construction and shallow foundation support due to its capacity to reduce plasticity, increase shear strength and enhance stiffness. The mechanisms governing lime treatment are well understood. Immediate cation exchange and flocculation modify the clay fabric and reduce plasticity, while long-term pozzolanic reactions between calcium hydroxide and reactive silica and alumina phases generate calcium silicate hydrates (C–S–H) and calcium aluminate hydrates (C–A–H), leading to progressive strength gain and improved compressibility behaviour. Although lime stabilization has proven highly efficient, it remains associated with non-negligible environmental impact due to calcination processes and CO_2 emissions. From a sustainability perspective, completely replacing lime is neither realistic nor necessarily desirable, given its well-documented reliability and predictable performance. A more viable strategy may consist in reducing the required lime content while maintaining or enhancing mechanical performance through complementary stabilization mechanisms. In this context, Enzyme-Induced Carbonate Precipitation (EICP) offers an innovative approach. In EICP, urease catalyzes the hydrolysis of urea, producing carbonate ions that react with calcium ions to precipitate calcium carbonate ($CaCO_3$). The resulting calcite crystals form interparticle bonds that increase stiffness and compressive strength. Unlike pozzolanic gels formed during lime stabilization, EICP generates discrete crystalline bridges that modify contact-scale stress transmission and may contribute to pore filling and permeability reduction. The combined use of lime and EICP therefore represents a chemo-bio stabilization strategy in which traditional chemical modification of clay fabric is supplemented by biomineral bonding. The central scientific question is whether EICP can compensate for a reduction in lime dosage by providing additional interparticle cementation, and whether the interaction between pozzolanic products and carbonate precipitation produces synergistic effects at the microstructural and macroscopic scales. Understanding this interaction requires linking mineralogical transformations, fabric evolution and shear strength development within a consistent geomechanical framework.

The main objective of this thesis is to evaluate whether partial replacement of lime by EICP treatment can maintain or improve the mechanical and hydraulic performance of fine-grained soils used in geotechnical applications. The study aims to determine whether a reduced-lime hybrid stabilization strategy can achieve

comparable shear strength parameters, stiffness and durability to conventional lime treatment, thereby contributing to lower-carbon ground improvement solutions. The research will investigate the influence of decreasing lime content on plasticity reduction, compressibility and shear strength, and assess whether the addition of EICP compensates for the reduction in pozzolanic bonding. Particular attention will be given to the evolution of effective shear strength parameters, stress–strain response and post-peak behaviour in order to determine whether hybrid stabilization modifies brittleness and failure mechanisms. The time dependent development of strength during curing will also be analysed to distinguish between early biomineral bonding and longer-term pozzolanic hardening.

Mechanical characterization will involve unconfined compressive strength testing to monitor strength development with curing time, as well as consolidated triaxial tests to determine

effective cohesion and friction angle. Oedometer tests will be performed to assess compressibility and preconsolidation pressure, allowing evaluation of stiffness evolution and yield stress modification. Where possible, permeability tests will be conducted to quantify changes in hydraulic conductivity associated with hybrid treatment. Durability will be assessed through controlled wetting–drying cycles in order to evaluate strength retention and structural stability. Microstructural observations using scanning electron microscopy will be carried out to identify the spatial distribution of hydration products and carbonate crystals, and to interpret the relationship between bonding morphology and macroscopic behaviour.

Language	**EN (english)**
Open to other master's programs	Yes
Eligible master's programs	M-IRARE
Number of topics	1

Supervision

Supervisor : Alessia Cuccurullo

Contact : alessia.cuccurullo@ulb.be