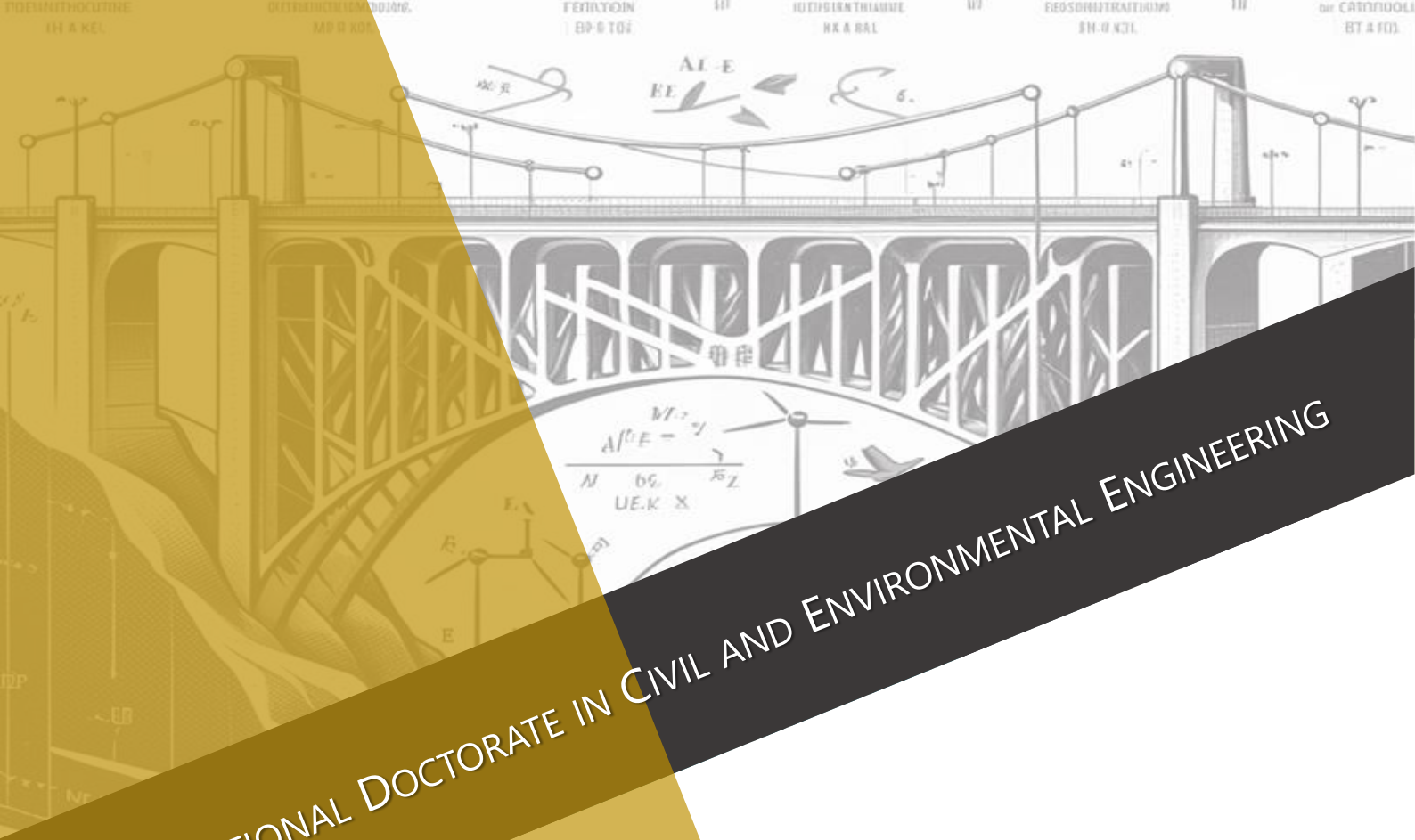

INTERNATIONAL DOCTORATE IN CIVIL AND ENVIRONMENTAL ENGINEERING

BOOK OF ABSTRACT

45th Plenary Meeting
Monday 29th October 2024
Monday 30th October 2024

Pisa - School of Engineering
Largo Lucio Lazzarino, 56122, Pisa, Italy

Firenze - School of Engineering
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International Doctorate in Civil and Environmental Engineering

Book of Abstract

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He.R.A. Heritage at Risk Analysis - Vulnerability of masonry churches for multi-layer single risk analysis

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Doctorate Thesis: He.R.A. Heritage at Risk Analysis - Vulnerability of masonry churches for multi-layer single risk analysis

Keywords: multi-hazard analysis, cultural heritage, conservation, landslide hazard, seismic hazard

Abstract:

The increasing frequency of natural disasters has prompted global efforts to develop strategies for Disaster Risk Reduction (DRR), with key milestones set by the Hyogo Framework (2005-2015) and the Sendai Framework (2015-2030). These initiatives emphasise understanding disaster risk, strengthening governance, and integrating DRR into recovery and development to "build back better." Cultural heritage plays a crucial role in community resilience, and the UNESCO World Heritage Committee has advocated for integrating heritage protection into DRR policies. However, challenges remain in managing the complexities of multi-hazard risk, particularly for cultural heritage sites, which face diverse threats, including earthquakes and landslides. The work seeks to address these challenges by proposing a standardised methodology for assessing multi-hazard risk to cultural heritage buildings, with a focus on religious structures. Italy's extensive inventory of churches, rich in historical and architectural significance, presents unique challenges for vulnerability assessment due to the complexity of their construction and the variety of hazards they face. The presented approach introduces two vulnerability indices tailored to landslides and earthquakes, designed to provide a quantitative analysis of the vulnerability of churches at the territorial scale. By concentrating on prioritisation criteria, the study aims to facilitate decision-making for the maintenance and protection of these structures, moving beyond single-building analyses. The methodology aligns with existing DRR frameworks and serves as a foundational step toward more comprehensive multi-hazard analysis, ultimately aiding in the allocation of resources for disaster risk reduction.

Microfibers remobilization from silty and sandy soil in turbulent environments

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Doctorate Thesis: Interactions between microplastic and sediments in freshwater and transitional environment: transport, infiltration and resuspension

Keywords: microfibers, remobilization, turbolence, shallow waters

Abstract:

Microplastic (MP) pollution in aquatic environments has emerged as a critical environmental issue. In freshwater MPs are known to accumulate in sediment beds where they can bury. Once buried they can resuspend due to highly energetic events. Synthetic microfibers (MFs) are becoming the focus of attention from the scientific community because of their abundance in natural environment. Moreover, due to their highly elongated shape, their behavior significantly differs from other organic or inorganic particles that can be found in the aquatic environment, consequently theoretical and empirical models already developed for the 3d-shaped MPs do not fit for MFs. With the aim to fill this knowledge gap, in this work the turbulence induced by an oscillating grid device was used to investigate the resuspension of MFs buried into the sediment bed. The concentration of resuspended MFs were correlated with the main geometrical and physical particles properties. We examined the effects of the shear rate and diameter of fibers, the polymer type, and the sediment characteristics showing that resuspended sinking MF concentration resulted inversely proportional to their settling velocity. In contrast, the concentration of floating MFs increased as their buoyancy velocity increased. The characteristics of the soil also played a key role, with more MFs resuspended under silty than in sandy soil conditions. Starting from statistically based observations, we defined a model able to predict the concentration of MFs resuspended along the water column. The physical meaning of the model was discussed, and outcomes were compared with experimental findings from other works.

A dynamic simulation-based approach to improve traffic efficiency and road safety in roundabout corridors

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Doctorate Thesis: A dynamic simulation-based approach to improve traffic efficiency and road safety in roundabout corridors

Keywords: Roundabout Corridors, Braess Paradox, Safety, Efficiency, ITS, Ramp Metering Systems, Simulations

Abstract:

This presentation outlines the key objectives and outcomes of my doctoral thesis, which can be summarized as follows. My research project is based on the premise that road intersections should no longer be assessed as isolated entities, but as integral components of a larger traffic system. The initial and most critical phase focuses on roundabout corridors, investigating equilibrium phenomena (such as Wardrop's Principles and the Braess Paradox) and analysing both safety and efficiency. The two primary objectives are: demonstrating that studying intersections as part of a system yields more accurate results and developing a standardized approach for analysing road corridors (such as roundabout corridors) to identify the most efficient and safe infrastructure configurations. This will be accomplished through dynamic simulations and geographic analysis using software tools like Aimsun, SSAM, and QGIS. In the second phase, I will examine emerging mobility and transportation technologies, with a focus on their application to roundabout corridors. A key objective here is to model and experiment with Intelligent Transportation Systems (ITS), such as Ramp Metering Systems, to evaluate their impact on the efficiency, emissions, and safety of intersection networks. My research will include experimental applications in Pisa, Italy, and Avignon, France, ensuring that the findings reflect real-world dynamics.

From Aerobic Granular Sludge (AGS) to Partial Nitritation Granular Sludge (PN-GS)

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Doctorate Thesis: Aerobic Granular Sludge technology for the transition to Biorefineries of Municipal Watewater Treatment Plants

Keywords: Biorefineries, Partial Nitritation, Ammonium Oxidizing Bacteria (AOB), Autotrophic Nitrogen Removal, Granular Sludge

Abstract:

This study explores the conversion of Aerobic Granular Sludge (AGS) into Partial Nitritation Granular Sludge (PN-GS) to improve energy efficiency in wastewater treatment processes. The research focuses on utilizing AGS biomass, sourced from full-scale treatment plants, as inoculum for a mainstream partial nitritation reactor, with the goal of accelerating reactor startup and bypassing the need for spontaneous aggregation of autotrophic microorganisms. The experimental work was carried out in Barcelona (UAB), highlighting both successes and challenges encountered throughout the process, followed by a reactivation period conducted in Florence, which allowed for further optimization and evaluation of the system. A Sequencing Batch Reactor (SBR) was designed to achieve high biomass concentrations and facilitate the enrichment of Ammonium Oxidizing Bacteria (AOB), while reducing the heterotrophic fraction. The reactor configuration, featuring mechanical mixing, enabled independent control of mixing intensity and oxygen levels, contributing significantly to system stability and overall performance. Results show that the PN-GS system achieved nitrogen removal rates comparable to those observed in other studies on granular reactors, demonstrating the potential for effective nitrogen management. The conversion from AGS to PN-GS preserved granule structural integrity, a key factor in maintaining microbial stratification and long-term stability, ultimately making this approach promising for full-scale implementation in wastewater treatment facilities.

New challenges for the textile industry

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Doctorate Thesis: Identification and development of strategies to increase the environmental sustainability of the Prato textile district

Keywords: textile industry, metals' removal, organic pollutants, reclaimed wastewater reuse, membrane treatment, textile dyeing

Abstract:

In accordance with the regulations set forth by GIDA SpA, industries in the Prato textile district can discharge their effluents into the sewer system, if they comply with the established discharge limits. The recently updated BAT Reference (Bref) document on the textile industry emphasizes the necessity of evaluating the capacity of wastewater treatment plants (WWTPs) to remove specific contaminants. The aim is to guarantee that textile companies operating under integrated environmental authorization are not subjected to new discharge limits based on the BAT-AELs indicated in the textile Bref. To this end, a monitoring campaign was conducted to ascertain the removal capacity of certain heavy metals and organic compounds at the Calice WWTP. The textile Bref also calls for curbing freshwater consumption. Prato already has a water recycling facility. However, the reclaimed wastewater has an excessive level of hardness, which presents a challenge for textile companies, who utilize ion-exchange resin technology, resulting in elevated chloride levels in the wastewater. Nanofiltration (NF) is an effective alternative for removing water hardness, potentially reducing chloride levels. In this regard, a steady-state chloride cycle model has been developed for the evaluation of trends in chloride concentration within the effluent of the refining plant. The NF system could be also implemented before the WWTP to reuse process water. Pilot-scale trials assessed the efficacy of NF in purifying and reusing textile dyeing effluent. The results demonstrated that reusing the permeate from NF-treated dyeing effluent did not affect the quality of the final product.

The role of landscape metrics in the Water-land-Ecosystem nexus

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Doctorate Thesis: Advancing Water-Land-Ecosytem Nexus Assessment through Hydrological Modelling and Landscape Approach

Keywords: Ecosystem services,Land use,Landscape metrics,Random forest,Hydrological modeling,Machine learning

Abstract:

This presentation highlights the use of random forest models to uncover non-linear relationships between landscape metrics and water-related ecosystem services. Forest patches, influenced by aggregation and shape complexity, impact runoff and groundwater recharge. Agricultural land, shaped by patch size and configuration, affects groundwater recharge and water yield. Vegetative cover, through connectivity and core area, plays a crucial role in determining runoff and water yield. By integrating these landscape metrics with hydrological variables, the study offers valuable insights for enhancing water resource management and landscape planning strategies.

Degradation models and time-dependent reliability assessment of prestressed concrete bridges with post-tensioned tendons

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Doctorate Thesis: A methodology for the real time reliability and residual life evaluation for Prestressed Concrete existing bridges with post-tensioned tendons subjected to corrosion phenomena

Keywords: Reliability, Time-dependency, Post-tensioned concrete, Bridges, Bayesian Updating

Abstract:

In the presentation, the aim and methodology of the PhD thesis are briefly introduced and explained, and the already done work is outlined. Then the problem of assessing the service life of existing bridges is specifically addressed. From the general issue of existing structure assessment, attention is focused on prestressed concrete bridges with post-tensioned cables. Notably, the presentation focuses on the progressive deterioration observed in such structural types, with particular attention given to the corrosive processes affecting cables. Probabilistic models to address corrosion development are introduced, calibrated and updated on the basis of data gathered. The framework employed for degradation and mechanical modelling is defined through a probabilistic approach, thereby enabling the calculation of the in-time probability of structural collapse and, hence, overall service life expectancy. Finally, these models are employed to perform the time-dependent reliability analysis of a prestressed concrete girder with post-tensioned cables.

Investigating the thermal performance of energy micropiles in cold Nordic regions

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Doctorate Thesis: The use of low enthalpy geothermal energy through the installation of micropiles

Keywords: Geothermal energy, energy micropiles, thermal performance, heating of buildings

Abstract:

The concept of using geostructures to harness ground energy for heating and cooling applications was introduced in the 1980s, starting with energy slabs and expanding to include piles, retaining walls, and tunnels. These structures, known as "energy geostructures," serve both structural and energy functions. Among them, pile foundations are particularly well-suited for geothermal energy use, as they extend into soil layers with stable temperatures unaffected by seasonal changes. In cases requiring structural retrofitting, foundation underpinning, or where noise and vibration limitations exist, micropiles are often the best solution. They are also highly effective in challenging ground conditions, as frequently encountered in Nordic regions. Given the high heating demand in the Nordic countries, this study examines the thermal performance of energy micropiles under winter conditions. The numerical study conducted over 30 days demonstrated that an energy micropile could deliver thermal power of around 31 W/m, showing its potential for heating applications in cold climates. A decline in performance over time was noted, but it eventually stabilized. For long-term viability, the integration of energy micropiles with other systems, such as district heating, solar panels, and other renewable energy sources, is recommended to balance the thermal load and optimize overall system efficiency. Further research should focus on the group effects and the combined thermo-mechanical behavior of energy micropiles.

Microaerophilic famine: selecting a PHA accumulating community with high accumulation capacity

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Doctorate Thesis: Towards polyhydroxyalkanoates synthesis with mixed microbial communities: exploring the uncouple feeding

Keywords: polyhydroxyalkanoate, mixed microbial community, microaerophilia

Abstract:

Polyhydroxyalkanoates (PHA) represent a class of biodegradable polymers potentially suitable for replacing conventional plastics. To overcome the high costs of current production using pure microbial cultures, research is moving fast towards the production of PHA through mixed microbial cultures (MMC). The feast and famine regime, together with an uncoupled feeding of carbon and nutrients source were revealed to be effective in selecting PHA accumulating communities. In considering commercial PHA production a large operational expense is aeration. In the literature there are some attempts to reduce aeration, introducing microaerophilic/anaerobic/anoxic steps, but a microaerophilic famine was never investigated. The aim of this work was to apply microaerophilic conditions in famine to explore the effects on the biomass selection (in terms of accumulation and settleability) under the assumption that microaerophilic conditions in famine could further disadvantage conventional heterotrophs and predation, in addition to reducing energy consumption. A PHA accumulating bacteria was selected in a 10 L sequencing batch reactor (SBR) operating under a feast-famine regime with uncoupled feeding and a microaerophilic famine phase (Dissolved Oxygen= 0-1 mg DO/L, avg. 0.3 mg DO/L). The biomass was fed a synthetic solution of acetate and propionate (80% - 20% COD basis) along with a nutrient solution containing ammonium at limiting concentrations. After 100 days of selection, the biomass grown under microaerophilic conditions exhibited significantly improved accumulation performance, achieving a maximum PHA content of 82% compared to 55% in the control reactor. However, the polymer quality was lower.

The Analysis of Mode III Fracture Toughness in Advanced Composite Materials

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Doctorate Thesis: Experimental Characterization and Numerical Modelling of Damage in Advanced Composite Materials

Keywords: Composite, Laminate, Fracture, ECT, Experimental, Numerical.

Abstract:

The primary focus of this research is the investigation of the interlaminar fracture toughness of structures, under mode III through a combination of experimental analysis and numerical modelling methods. The assessment of mode III fracture toughness is closely related to the interaction at the interface of the composite beams in three main fracture modes, such as Double Cantilever Beam (DCB) for mode I, End Notch Flexure (ENF) for mode II, Edge Crack Torsion (ECT), or Split Cantilever Beam (SCB) for mode III. To simulate the mode III, a specimen with an initial crack between its interface has been analysed by FEM software (Abaqus) under the ECT test. Additionally, the Virtual Crack Closure Technique (VCCT) has been applied between the composite interface to evaluate the strain energy release rate (SERR). At last, the main purpose of this research is characterization and standardization of mode III fracture toughness to assess the strain energy release rate.

Laboratory analysis of plastic particle transport in vegetated patches

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Doctorate Thesis: Influence of CSOs on spatio-temporal distribution of plastic in rivers

Keywords: microplastics, environment, rivers, vegetate patches

Abstract:

The study of plastic presence in water ecosystems, such as rivers, lakes, and oceans, has gained attention due to the various physical and biochemical processes it triggers. Despite this focus, there are still knowledge gaps, especially regarding the transport dynamics of plastics in rivers. During river transport, plastic particles can accumulate on riverbeds, structures, and riparian vegetation. Recent research highlights the crucial role of riparian vegetation in this process, as it can trap plastic litter during river flow and later release it during floods. Specific vegetation types, such as trees and shrubs, are particularly effective in capturing flat plastic elements. This research examines the interaction between microplastics and riparian vegetation. Through laboratory experiments, the study aims to understand how flexible vegetation traps or divert plastics, focusing on the spatial distribution of trapped particles within vegetated areas.

Water Stress and Ecological Flows: A Cross-Basin Sensitivity Analysis in the Mediterranean

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Doctorate Thesis: Exploring the sensitivity of water stress indices and ecological flow to change

Keywords: Water resources, Ecological flows, Change, Hydrological modelling

Abstract:

This research investigates the sensitivity of water stress indices and ecological flows in two Mediterranean river basins: the Northern Apennine Hydrographic District in Tuscany, Italy, and the Jucar River Basin in Spain. These basins face growing pressure on water resources due to climate change, land use changes, and increasing water demand. The study employs hydrological modeling to assess water availability under current and future conditions, explicitly considering the interconnected nature of surface water and groundwater resources. In Tuscany, the MOBIDIC hydrological model simulates surface and groundwater resources, providing a holistic view of the water system. In the Jucar River Basin, the TETIS and MODFLOW models simulate surface water and groundwater dynamics, allowing for an integrated assessment of these interconnected resources. This comparative approach enables a deeper understanding of how surface and groundwater systems respond to changing climatic and environmental conditions. The research aims to identify critical vulnerabilities and inform sustainable water management strategies in these regions by comparing water stress indices and ecological flows under various scenarios. The innovative approach of integrating surface water and groundwater modeling provides valuable insights for climate change adaptation and water resource planning in Mediterranean river basins facing similar challenges, empowering the audience with practical knowledge.

Wind risk analysis of urban trees

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Doctorate Thesis: Multi-risk analysis of natural hazards in urban green environments

Keywords: Trees, Uprooting, Risk Analysis, Wind, Probabilistic Analysis.

Abstract:

Trees play a vital role in urban environments by enhancing quality of life, supporting biodiversity, and regulating the local climate. However, effective management is crucial to maintaining these benefits while mitigating the risks trees may pose to people and property, particularly in strong winds. Windthrow, or the uprooting of trees during storms, is one potential risk that prompted the development of two complementary models in this study to evaluate tree behavior under wind load. The first model focuses on the belowground dynamics, examining the interaction between tree roots and soil, using an innovative combination of a space colonization algorithm and embedded beam elements within a 3D finite element software called Plaxis. This model generates moment-rotation curves that are then fed into the second model, which assesses aboveground dynamics by analyzing wind forces on a simplified tree structure. This determines the rotation at the tree base and evaluates its stability. The overall tree failure analysis is probabilistic, taking into account various influencing factors through probability distribution functions. The fragility curve is derived from Monte Carlo simulations, offering insight into failure probabilities for different wind speeds. The rainfall effect, influencing the water table, is integrated into the root-soil model, further refining the analysis. Ultimately, the combination of wind hazard, tree fragility, and replacement costs culminates in a comprehensive risk assessment of trees under wind loading.

IGA-C beams formulation for general hyperelastic materials

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Doctorate Thesis: IGA-based computational methods for the analysis of complex structural systems, with application to artery stents

Keywords: Isogeometric Analysis, Curved Beams, Hyperelastic material, 3D constitutive model, Isogeometric Collocation

Abstract:

In my presentation I will show the main objects of my research. I will explain the main goal and the tools regarding my work, focusing on the modelling and the numerical simulation of biomedical devices, like artery stents. These stents are structures with complex shape and topology, that are modelled with beam elements, instead of using 3D solid elements, to reduce the computational costs, ensuring a high efficiency in the formulation. Since these complex structures are generally made with complicated materials, which are usually described only for 3D continuum, it is often advantageous to use a 3D material law. For this reason, an important part of the research activity is to define an isogeometric beam formulation in which general 3D constitutive laws are employed. Instead of adopting classical one-dimensional constitutive models for beams, the objective is to adopt a general 3D constitutive model for a continuum body in beam elements, by maintaining the beam kinematic assumptions. The formulation that I have defined is obtained starting from the 3D constitutive law for a solid, by adopting a tested algorithm capable of statically condense the strains not compatible with the stress conditions of a beam element. Some numerical simulations prove the efficiency of the proposed methods, paving the way for interesting applications in structural analysis. With this formulation it is possible to model better the real simulation of real materials. The final goal is to analyze artery stents accurately and efficiently, including geometric and material nonlinearities.

Urban Mining and Life-Cycle Thinking: new approaches in solid waste management towards a circular economy

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Doctorate Thesis: Urban Mining and Life-Cycle Thinking: new approaches in solid waste management towards a circular economy

Keywords: Municipal solid waste management, Solid waste composition, Separate collection efficiency, Life Cycle Assessment

Abstract:

The presentation will cover research conducted both in Italy and during a period spent at the Autonomous University of Barcelona. In Italy, the focus was on municipal solid waste (MSW) characterization and evaluating the efficiency of the separate collection system in Tuscany. To provide an overall balance of waste composition and collection efficiency, all waste fractions, including residual waste, were analyzed. Additionally, a monitoring campaign was conducted to measure the real fuel consumption of vehicles used by waste management companies for collection services, characterized by frequent start-and-stop operations. Direct CO2 emissions were estimated and compared with national databases on freight or public transport vehicles commonly used in conventional Life Cycle Assessment (LCA) studies. In Spain, we applied Material Flow Analysis (MFA) and LCA methodologies to evaluate the MSW management (MSWM) system in Catalonia. Using scenario analysis, we examined how variations in contaminants management could affect the environmental performance of the system. An additional phase of the study will involve developing a scenario analysis with varying separate collection rates (SCR) to study its effects on recycling rates (RRs) and environmental impacts. This approach will help identify potential improvements in waste management processes. The next step is to conduct an LCA of the MSWM system in Tuscany and compare the results of the two case studies: Catalonia and Tuscany. This comparison will provide insights into the environmental impacts of both systems, highlighting potential areas for optimization and the influence of local collection practices.

Determination of channeled emissions fingerprints aimed at identifying and localizing olfactory nuisances

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Doctorate Thesis: A sensing network for high spatio-temporal resolution monitoring of fugitive emissions from wastewater treatment plants

Keywords: Solid-Phase MicroExtraction, nuisance odours emission fingerprint, Gaussian Plume model

Abstract:

Observation and characterization of environmental pollution in industrial areas are particularly important to provide indications on responsibility for nuisance odours and advise on policy interventions. The aim of this study is to use the Solid-Phase MicroExtraction (SPME) technology to measure airborne VOCs, in no-equilibrium conditions directly coupled with atmospheric measurements taken on a mini-drone, to identifying a fingerprint of the channelled emissions. The SPME has been developed and validated in recent years to measure different categories of VOCs using various sorbent phases. Lab gas chromatographic/mass spectrum analysis of collected SPME fibres allowed the detection of a wide range of VOCs. The combination of this information collected during the monitoring campaign allowed the implementation of a Gaussian Plume model that estimates the VOCs' concentration on the ground. SPME fiber was exposed to the channelled emission for 30 seconds during the mini-drone flight. The exposure time is a compromise between two contrasting requirements: to lower detection limits for all compounds (since the longer is the exposure time the larger will be the mass of compounds present on SPME fibers) and to increase the possibility to achieve a successful sampling (the emission could be stopped once the presence of the sampling device is noticed). From the results obtained, it emerges that coupling SPME technique and mini-drone fully satisfies the requirements for assessing the fingerprint of a channelled emission and is suitable for the implementation of a high spatiotemporal resolution monitoring system of odour nuisance the final goal of the research.

Benchmark Development for SHM Data: Classifying Sensor Faults, Malfunctions, and Distinguishing Damage Types

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Doctorate Thesis: Machine Learning Techniques for Structural Health Monitoring Long-Term Damage Detection

Keywords: Synthetic Data; Single-Degree-of-Freedom System; Environmental and Operational Variability; Fast-Varying Damage; Slow-Varying Damage; Sensor Faults

Abstract:

The primary objective of this research is to investigate how to distinguish between fast-varying damage (e.g., sudden events like seismic activity) and slow-varying damage (e.g., ageing-related deterioration) by analysing long-term Structural Health Monitoring (SHM) data acquired from historical structures. Damage can manifest suddenly, immediately impacting structural behaviour, or gradually accumulating over time. The latter is especially important when studying historical constructions. This research will tackle these distinctions using a Physics-Informed Machine Learning (PIML) approach. The project is divided into three key phases: (1) gathering and pre-processing long-term SHM data, (2) extracting relevant features, and (3) applying machine learning algorithms to classify fast-varying and slow-varying damage. Significant challenges include preparing case studies, comparing physical and latent features with neural networks and autoencoders, and combining data with different sampling rates to capture various damage types. Environmental and operational variables are also considered for predicting structural responses and estimating remaining useful life. This presentation will emphasise the development of a numerical benchmark for SHM data that supports these tasks, including the classification of sensor faults and malfunctions and the distinction between damage types. Based on a simulated SHM case study, the benchmark includes dynamic and static measurements under different damage and failure scenarios. The presentation will use this benchmark dataset to describe the state of progress on sensor fault classification, slow-varying vs fast-varying damage distinction, and methodology development.

Monitoring megacusp shoreline undulations from multispectral satellite images

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Doctorate Thesis: Coastal areas monitoring through satellite remote sensing

Keywords: Shoreline extraction, Megacusps, Sentinel-2, PlanetScope, Multispectral imagery

Abstract:

Coastal zones, particularly sandy beaches, are highly dynamic environments subject to a variety of natural and anthropogenic forcings. The shoreline is the most widely used indicator of beach changes, and it can display undulations at different spatial scales. One of them are megacusps, which consist of periodic seaward and landward perturbations that can significantly modify beach width and affect its users. This study explored the potential of using multispectral satellite-derived shorelines, specifically from Sentinel-2 (S2) and PlanetScope (PLN) platforms, for detecting and monitoring megacusps formation and their dynamics over time. The tool developed for an accurate shoreline detection utilized a combination of spectral indices, alongside with both thresholding and unsupervised clustering techniques. Validation was performed on three tideless Mediterranean beaches, comparing with high-resolution orthomosaics and in-situ GNSS data. Results of the shoreline detection phase shown a good subpixel accuracy (with a mean absolute deviation of 1.5--5.5 m depending on the satellite type). In relation to the megacusps monitoring tool, the results prove that satellite shorelines derived with our tool can be used to robustly and accurately characterize megacusps, capturing their amplitude and wavelength, as well as to monitor their evolution using different potential metrics. Our findings demonstrate that multispectral satellite imagery provides a viable and scalable solution for monitoring shoreline undulations, enhancing our understanding and offering an interesting option for coastal management and erosion mitigation.

Hypersaline wastewater treated using sequencing batch reactor (SBR) and integrated fixed film activated sludge reactor (IFAS) inoculated with solar saltern sediments.

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Doctorate Thesis: Biological processes for treatment and resource recovery from industrial wastewater based on selection of halophilic and halotolerant microbial consortia.

Keywords: Hypersaline wastewater, halophiles, sequencing batch reactor, integrated fixed film activated sludge, biomass settling, diethylen glycol

Abstract:

Approximately 5% of total wastewater are saline and hypersaline. The increasing world population and growing industrialisation drive an increase in the production of this wastewater. Hypersaline stream (salt concentration >35 gNaCl/L) is generated by various industrial sectors (e.g. agro-food, tanning, chemical, oil&gas, pharmaceutical, textile) and is often associated with a high organic load. A full assessment of the feasibility of using bio-treatment for hypersaline wastewater is not available Conventional microbial consortia cannot be used under hypersaline conditions due to the absence of strategies to regulate osmotic pressure and prevent cell death. Otherwise, halophilic microorganisms live and thrive in hypersaline conditions. Studies are scarce in the literature regarding the utilisation of these microorganisms for wastewater treatment. The metabolic limitations of halophilic biomass and the commonly reported challenges, such as low oxygen solubility, poor biomass setting, set-up corrosion, and effluent turbidity, may have discouraged further investigation in this area. This presentation will be focused on the performances of a sequencing batch reactor (SBR) and an integrated fixed film activated sludge reactor (IFAS). The reactors were inoculated with hypersaline sediments and synthetic hypersaline wastewater (110 gNaCl/L) containing sodium acetate (70%), yeast extract (10%), and diethylene glycol (20%) (a pollutant present in some wastewaters produced by the oil and gas industry).

Employing IGA-BEM for calculation wave loads on offshore structures

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Doctorate Thesis: Offshore wind energy: advanced computational models for the simulation of large floating turbines

Keywords: IGA-BEM, Offshore structure, non-linear waves, B-spline

Abstract:

The Boundary Element Method (BEM) has been extensively applied to compute wave loads and other hydrodynamic properties related to the interaction between offshore structures and waves. In the traditional approach, which uses low-order elements, the submerged surface of the structure is modeled by dividing it into many small elements. The velocity potential is typically approximated by assigning a constant value to each element. In this study, we discuss two recent advancements in our research. First, modifying desingularized method for complex geometries to solve singular integrals where appears in BE. Second, employing a novel technique, Iso-Geometric, for geometry representation and combining in BEM solver (IGA-BEM) where the submerged surface and free surface can be represented exactly, or approximated to a high degree of accuracy by B-splines. Also the velocity potential is approximated with the same degree of basis function. In this study, after introducing the model equations and the numerical technique, first model validation for a non-linear wave tank is given. Numerical result were compared with analytical solution and effective parameters on accuracy identified. Then, the solver were applied for a fixed structure application. The proposed method is validated with other numerical methods with good agreement.

The evaluation of driving safety and comfort while a vehicle driving on a long-span bridge under non-synoptic crosswind impacts

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Doctorate Thesis: The evaluation of driving safety and comfort while a vehicle driving on a long-span bridge under non-synoptic crosswind impacts

Keywords: Skew wind; Gust wind; Typical wind curve; Adverse yaw angle; Accident risk ratio; Road vehicle driving safety; Tower aeras

Abstract:

The highway traffic construction was greatly boosted within the past decades since the growth perspective of the economic and society. Especially, the growing requirements of transportation system capacity also promoted the evolution of long-span bridges construction in the western provinces in China, while the center of economic and construction gradually transferring to those areas nowadays. Meanwhile, the driving safety already became a striking issue for vehicles passing through long-span bridges in mountain valley areas, and it's therefore gradually become the controlling factor at the service stage of long-span bridges. This doctoral work addresses this topic, aiming to enlarge the understanding of effects of strong non-synoptic cross wind on the driving safety states and comfort while a vehicle driving on a long-span bridge in mountain valley area, basing on the research results of field measurements, wind tunnel tests, and computation fluid dynamic (CFD) and finite element method (FEM) simulations.

Exposure and vulnerability to heatwaves and air pollution: assessments in urban environments

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Doctorate Thesis: Exposure and vulnerability to heatwaves and air pollution: assessments in urban environments

Keywords: Heatwaves, air pollution, risk components, environmental injustice, low-cost sensors

Abstract:

Residents of a city exposed to adverse environmental conditions, in terms of both elevated heat-stress and poor air quality, may experience health risks that can be exacerbated by socioeconomic status. The first objective of this research focuses on developing an integrated risk assessment framework for Prato (Italy) by combining information on concurrent hazards (summer heat stress and winter air pollution), socioeconomic vulnerabilities indices (Income deciles and Deprivation Index), and demographic exposure (elderly population fraction). The main novelty relies on the use of multiple data sources, which were merged through a novel approach incorporating observed measurements of air temperature and air pollution (PM10 and PM2.5 concentrations) at fine time and spatial resolution through a dense IoT sensor network developed by Institute for BioEconomy of the Italian National Research Council (CNR-IBE). Within this risk assessment framework, the second objective is to explore the reduction of urban heat intensity—one of the analyzed hazards—through evaporative cooling, using recovered water to irrigate green areas in Prato. This scenario can be evaluated with the support of GIDA S.p.A., a joint-stock company located in Prato focused on wastewater treatment and recovery for industrial use. However, only a small fraction of the recovered water is currently utilized, with the remainder left unused.

A framework for the integration of BIM models, facility management services and IoT data through semantic web technologies

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Doctorate Thesis: From BIM to DT. Data integration in life cycle information management of existing assets

Keywords: BIM, IoT, Linked Data, OWL, time series DB

Abstract:

Today, information exchange in the AECO industry, in the different phases of the building process, typically occurs through file transfers in heterogeneous formats, with limited communication between parties. This results in potential data management is-sues, such as redundancy and write errors. While efforts to standardize data exchange date back to the 90s, with formats like STEP and IFC, the challenge of interoperability remains. It's important therefore to set up integrated management systems and interop-erable cloud-based technologies. The rise of open semantic standards by W3C and other organizations in recent decades has been significant, but a cohesive connection between different ontologies is necessary for the realization of Digital Twin technology, which represents the life cycle of a building, not just the design phase. After a brief introduction to Linked Data and its applications in the building industry, this work focuses on developing a data management methodology for the use and management of existing real estate assets by public administrations, with emphasis on integrating BIM models with existing asset databases using semantic web technologies like RDF, OWL, and SPARQL.

Biocoal production and phosphorous recovery from stabilized sewage sludge and aerobic granular sludge by the integration of slow pyrolysis, hydrothermal carbonization, and chemical leaching

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Doctorate Thesis: Recovery of carbon and critical raw materials from civil sludges through integrated thermochemical processes

Keywords: aerobic granular sludge, biocoal, chemical leaching, hydrothermal carbonization, phosphorous, recovery, sewage sludge, slow pyrolysis

Abstract:

This work aimed at studying the integration of chemical leaching with slow pyrolysis and hydrothermal carbonization (HTC) as a strategy for the valorisation of sewage sludge from conventional activated sludge process (CAS) and aerobic granular sludge technology (AGS). The processes integration targets the recovery of phosphorous, as an inorganic fertilizer, and of a biocoal to be applied as a fossil coal substitute. After processing sludge in laboratory by slow pyrolysis (by a thermogravimetric analyser) or HTC (by autoclave), acid leaching by HNO3 was applied to the produced solids (chars) aiming to increase their C content and extract P (together with other inorganic compounds) in the leachate, and then by precipitation. The biocoal from CAS and AGS pyrochar leaching showed an ash content around 47% and 20% respectively, and a C content around 37% and 55% respectively; the ash content of the biocoal from CAS and AGS hydrochar leaching was around 45% and 10% respectively, while the C content was around 35% and 62% respectively. By leaching, 100% P was extracted, but Si was retained in the solid material. According to the Van Krevelen diagram, the biocoals from pyrochar are comparable to a coal, while hydrochar-derived biocoals showed a higher H/C ratio than coal. The precipitated solids showed up to 7% P content with a potential application in the fertilizers sector. In conclusion, the integration of slow pyrolysis/HTC and leaching are promising strategies for sludge circular valorisation, enabling to produce bio-based products (a coal and a fertilizer) from a waste.

Wastewater based epidemiology - Open issues in surveillance

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Doctorate Thesis: Leveraging wastewater data for epidemiologic surveillance

Keywords: Wastewater, epidemiology, surveillance

Abstract:

In recent years, wastewater has been proposed as an effective tool for pandemic surveillance, particularly in those cases where extensive clinical testing is infeasible. While the link between viral concentration measurements in wastewater and pandemic trends is well documented, the presence of complex noise sources affecting the data led a part of the scientific community to consider wastewater incapable of being used as a standalone source for robust epidemiologic modelling. In this presentation, I will discuss the impact of several noise sources on the wastewater measurements taken in 6 different wastewater treatment plants in Tuscany during 2022-2023 to detect the presence of SARS-CoV-2. I will show how a GAMM model can help us better understand the underlying phenomena leading to a mismatch between clinical test data and wastewater concentration. Finally, I will discuss the current approaches that we are considering for leveraging wastewater data to carry pandemic surveillance, focusing on the current open issues we are facing.

A new last mile freight transport system based on platoons of automated vehicles and dynamic management of split up locations

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Doctorate Thesis: Design, simulation and optimization of innovative strategies for the management of freight logistics based on an urban distribution center in port cities

Keywords: Van-platooning system, UDC localization problem, last mile city logistics

Abstract:

The research in this PhD period has regarded further advances in urban logistics solutions, in particular on the van-platooning system. In the previous research, it was considered that platoons split up and recompose at the same Split Up Location (SUL): this is called "static scenario". In simulation, it has been drafted a "dynamic scenario" in which vehicles may belong to a different platoon in the return trip from the SUL to the UDC and in general vehicles may return to a different SUL from where the platoon they belonged to was split up. This idea has been developed with the intention of reducing the waiting time at SULs of the other vehicles forming the platoon. This proposed scenario has been applied to Livorno city center. Three main scenarios have been analyzed. In the first static scenario (1) the UDC is located in Interporto Toscano Amerigo Vespucci, while in the second (2) and third (3) scenario, one static and one dynamic, the UDC is located closer to the city center in order to shorten travel times, this because platoons travel at a low speed (40/50 km/h). The results of the application have shown that on one side there is effectively a reduction of waiting times, however the activity times of drivers have increased, indeed the static scenario is the result of an optimization while dynamic scenario is only optimized in dynamic and because of this the quality of the result is not comparable with the static scenario.

Inflation of a circular arch beam

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Doctorate Thesis: Theory of inflatable beams

Keywords: Beam, inflation, circular, arch

Abstract:

In this presentation I analyze the response of a circular arch beam under the inflation due to an internal pressure. The cross section of the beam is hollow and circular, but also thin-walled. Two cases are considered. In the first, the beam has free ends, while in the second the beam ends can translate only in the radial direction and cannot rotate. The first problem is isostatic and shows the response of an unconstrained beam due to inflation, while the second is hyperstatic and is representative of the inflation of a torus. The analytical solutions of these problems are obtained and compared. Both beams remain circular after inflation, as expected. Also, the cross sections remain orthogonal to the beam axis in both cases. Moreover, in the second problem the cross sections do not rotate. The axial stretch is positive in both problems, but greater in the first. The final radius is bigger than the initial one in both problems, as expected. The axial force is positive in both problems and of the same magnitude. While in the first case the bending moment is zero, in the second the bending moment pulls the fibers on the inner side of the arch. This is due to the fact that in the second problem the initial and final cross sections cannot rotate. In both cases, all the fibers are in tension and the greater stress is on the inner side of the arch. However, the maximum stress occurs in the second problem.

Dynamics and Response of Free Alternate Bars to Sediment Supply Limitation: An Experimental Investigation

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Doctorate Thesis: Modeling sediment transport and large-scale bedform dynamics in rivers

Keywords: Rivers, Alternate bars, Sediment transport

Abstract:

Dynamics and Response of Free Alternate Bars to Sediment Supply Limitation: An Experimental Investigation This study investigates the response of sand-bed river bars to conditions of reduced sediment supply, expanding upon previous research that has primarily focused on gravel-bed systems. Although the influence of flow unsteadiness on river bar behavior has been well-documented (Carlin et al., 2021; Tubino, 1991), the role of sediment supply in shaping bar morphology remains complex and variable. Key studies by Lisle et al. (1993) ,Venditti et al.(2012), (Nelson & Morgan (2018), and Bankert & Nelson (2018) highlight the significant impact of sediment dynamics on river bars, primarily within the context of gravel-bed systems. Some of these studies report varying results, underscoring the need for context specific study. Given that sand exhibits different mobility characteristics compared to gravel, this research aims to address the gap by examining the persistence of alternate bars in sand bed river under conditions of significantly reduced sediment supply. A more realistic methodology, employing an exponential receding sediment supply function, is being utilized to systematically reduce sediment availability, allowing for a controlled assessment of its impact on sand-bedded river bars. The findings are expected to provide insights into the behavior of sand-bedded bars under sediment limitation and unsteady flow, contributing to a broader understanding of riverine environments.

Art loans for exhibitions: technical and spatial aspects

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Doctorate Thesis: Integrating spatial data for artworks and venues to improve the organisation of art exhibitions

Keywords: Loans, spatial data, BIM

Abstract:

Organizing art exhibitions is a complex task involving various public and private cultural institutions. Given the fragility and value of artworks, careful planning is essential. From the selection of pieces to the final exhibition, institutions must exchange critical information, particularly regarding physical and material conditions. Best practices dictate that the receiving museum provides a facility report, detailing the exhibition space's geometry, construction features, environmental conditions, and security measures. The lending institution, in turn, communicates the artwork's physical attributes (size, weight, etc.), handling requirements, and environmental needs. During the exhibition design phase, this information is continuously reviewed and shared among stakeholders. However, this process remains largely manual. Most museum content management systems (CMSs) are text-based and do not use spatially organized data, making information exchange inefficient. Integrating CMSs with Building Information Modeling (BIM) could streamline exhibition planning by representing artworks as BIM entities. This can be achieved by reusing existing or newly collected data. Thanks to ongoing or planned digitization projects, many museums already possess 3D spatial data of their collections. Similarly, many institutions have spatial data of their exhibition venues. While fully modeling historical museums can be expensive, it is often sufficient to create models that include only the necessary spatial, structural, and system information for exhibition planning, greatly improving coordination and efficiency.

Fully Coupled Thermo-Viscoelastic Model for Shape Memory Polymer Beams: An Isogeometric Collocation Approach

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Doctorate Thesis: Isogeometric analysis-based models for shape changing structures with applications to patient-tailored stents

Keywords: Shape memory polymers, Coupled thermo-viscoelastic beams, Generalized Maxwell model, isogeometric collocation method, Finite deformation, Bishop frame.

Abstract:

The research project focuses on the development of an advanced computational model for simulating the shape-changing process of patient-tailored cardiovascular stents, specifically targeting thermo-responsive shape memory beams. The study proposes a fully coupled thermo-viscoelastic shape memory polymer (SMP) model based on the isogeometric collocation (IGA-C) method, which allows for accurate simulation of SMP beams undergoing finite deformations while also accounting for thermal effects. The model integrates the generalized Maxwell approach for viscoelastic materials, coupled with thermal field equations to account for temperature-dependent material properties. Temperature is treated as an unknown field alongside displacement and rotation variables. The displacement-based formulation significantly reduces the number of unknowns, eliminating the need for extra variables associated with rate-dependent material behavior. The governing equations are discretized using the IGA-C method, which not only maintains high accuracy in geometry representation but also bypasses the need for element integration, improving computational efficiency. The use of the Bishop frame combined with the exponential map for SO(3) allows for a robust and accurate computation of beam curvature and its derivative. This formulation overcomes the limitations of the Serret-Frenet frame, especially in regions where local curvature vanishes. Numerical examples demonstrate the model's ability to simulate SMP beams with complex geometries and thermal influences, advancing the design of adaptive stents and contributing to the development of personalized, shape-changing cardiovascular devices in medical applications.

A Hybrid Approach to Investigating Factors Influencing Injury Severity: Integrating Interpretable Machine Learning with Logit Models

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Doctorate Thesis: Advancing Road Traffic Safety: Deep Learning for Traffic Modeling and Strategy

Keywords: Injury severity analysis, traffic accidents, machine learning, deep learning, logit

Abstract:

This study analyzes five years of traffic accident data from the Bouches-du-Rhône region in France to investigate the factors influencing injury severity in light vehicle collisions on municipal roads—one of the most common accident scenarios. By integrating interpretable machine learning techniques with statistical methods, this research provides a thorough assessment of injury severity in traffic accidents. Firstly, the dataset was balanced using the Wasserstein Generative Adversarial Network (WGAN) and compared with traditional balancing techniques, Synthetic Minority Over-sampling Technique (SMOTE). Random Forest model was subsequently developed to predict injury severity, capturing both main and interaction effects. Shapley values were used to visualize how features impact different injury types, revealing that factors such as age, safety equipment usage, and obstacles significantly influence injury outcomes. To further explore these effects, a Multinomial Logit (MNLogit) model was employed, quantifying the influence coefficients and marginal effects of each factor and illustrating their contribution to varying levels of injury severity. This research not only advances the understanding of risk factors in traffic accidents but also works as the prior knowledge for traffic safety modeling.

Studying numerical meshless methods and neural networks for solving partial differential equations

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Doctorate Thesis: Development of neural networks based on data for non-Gaussian autoregressive processes constrained with balance equations

Keywords: meshless methods, RBF collocation method, ANN, PINN

Abstract:

Governing equations of engineering problems are usually complex and sometimes the boundary conditions are tangled. Subsequently, solving equations is a very important challenge in engineering issues. In recent years, many numerical methods have been used for this purpose. Mesh-based and meshless methods are the most famous numerical methods. Mesh-based methods have made great progress in recent years and are widely used in industry. However, they are not able to provide acceptable performance in some issues such as large deformations and complex geometries. Meshless methods introduced to overcome the disadvantages of mesh-based methods, which are classified in two major categories: weak form and strong form. The weak forms are based on energy and are acceptable from the point of view of stability and accuracy, but high computational cost has led to the ineffectiveness of these methods in engineering issues. Collocation of strong-form is an alternative approach to handle domain integration of weak-form method. The computational cost is lower, but accuracy and stability are the downsides of this method. As mentioned above, solving partial differential equations in mechanical problems with traditional methods is challenging in some circumstances. Therefore, ANN has attracted a lot of attention in recent years. As ANNs require big data, they cannot be efficient enough for engineering problems. On the other hand, computational mechanics involve solving differential equations and the number of data is limited. thereby, efforts were made in this field to compensate for the lack of data using physics equations which called physic-informed neural networks.

Artificial Intelligence for hydrological extremes analysis in rural and mountain area

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Doctorate Thesis: Artificial Intelligence for hydrological extremes analysis in rural and mountain area

Keywords: Flood risk, flood prediction, AI, hydrology

Abstract:

Flood prediction and risk management are critical for protecting rural and mountainous regions, which are often characterized by smaller, steeper watersheds that present unique challenges for hydrological modelling. This research aims to improve the accuracy of flood prediction in these regions while leveraging the advantages of large-scale river discharge prediction models. By investigating both the hydrological requirements and the potential of Artificial Intelligence (AI) techniques, this study aims to advance the current hydrological modelling methods, with three main objectives: (i) identifying the most relevant catchment descriptors for effective large-scale flood modelling, (ii) studying the primary flood drivers (such as rainfall, soil moisture, and temperature) and their combined effects on river floods, and (iii) exploring how blending hydrology with advanced AI modelling can support and improve flood prediction. Initial analyses comparing the European Flood Awareness System (EFAS) discharge predictions with the large-scale hydrological dataset "LamaH-CE" reveal that EFAS predictive performance declines in smaller catchments. These limitations highlight the pressing need for innovative approaches, particularly in rural and mountainous areas, where the distinct hydrological behaviour of smaller, steeper watersheds requires more tailored and adaptive predictive strategies.

Utilizing a Stilling Wave Basin to Reduce Overtopping of Sloping Armoured Seawalls

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Doctorate Thesis: Utilizing a Stilling Wave Basin to Reduce Overtopping of Sloping Armoured Seawalls

Keywords: Wave-Overtopping Reduction, Armoured Seawall, Stilling Wave Basin, Climate Change, Sea Level Rise, Adaptation Measures

Abstract:

The work presents a study that is based on 2D small-scale experimental models and focuses on the modification of the Stilling Wave Basin (SWB) crest for low-crested inclined armoured seawalls. The objective of this study is to effectively reduce wave overtopping. The comparative analysis of various SWB geometries and the reference tests without SWB conducted in this study support the experimental results, which demonstrate a substantial reduction in wave overtopping as a result of SWB crest modification. The SWB design parameters, which encompass the seaward and landward storm wall heights, the cross-shore length of the SWB, and a blocking coefficient that represents the effectiveness of water drainage from the SWB, are used to systematically evaluate the influence of various SWB geometries on overtopping. The reduction in overtopping is quantified and subsequently presented through the introduction of a reduction factor that is structured as a function of the primary SWB design parameters, utilizing the 146 experimentally tested conditions. This method estimates the mean overtopping discharge in scenarios where SWB crest modification is applied to low-crested sloping armoured seawalls by incorporating this reduction factor into the widely accepted EurOtop (2018) overtopping prediction formula.

Scenario Analysis of flood Resilience Using system dynamics modelling: the case of Florence

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Doctorate Thesis: Community Resilience to Flooding Risks Under Climate Change: Case of Cultural Cities

Keywords: Flood, Resilience, System Dynamics Modelling, Scenario Analysis

Abstract:

Community resilience and its dynamic response to flooding disasters are investigated in this research. The study involves the application of a flood resilience model in a culturally significant city like that of the city of Florence and aims for the protection of its world renown cultural assets from damages and total destructions. The intended results would aim to present a quantitative and dynamic evaluation of resilience through the use of System Dynamics Modelling (SDM) in the setting of a significantly historical city at the risk of flooding. For the research, twenty indicators of resilience were identified and categorized under four groups of resilience namely economic, social, organizational and infrastructural dimensions. System dynamic (SD) approach, capable of simulating the complex interaction of various components with their the temporal variations, was adopted for modelling and analysis. Data for each of the identified indicators was collected from various sources but mainly from the commune of Florence open data platform. The different sets of data collected have different scales and ranges which makes it illogical to use them in their raw values. Thus, data normalization was adopted. Weights were also assigned to each indicator using the Critic method. Continuing on previous study which has tried to track economic, social, organizational and infrastructural resilience components over a period of twenty two years between the years 2000 and 2022, this particular research tried to simulate the future scenarios of the city.

AI and CV methodologies for digital transition and the optimization of archival 2D/3D data of cultural heritage,in order to capture and retain information of reflectivity, transparency, homogeneous textures, non-Lambertian surfaces.

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Doctorate Thesis: AI methodologies for the digital transition and the optimization of archival 2D/3D data of cultural heritage, acquired with integrated geomatic techniques

Keywords: ARTIFICIAL INTELLIGENCE, 3D-GAUSSIAN-SPLATTING, NERF, COMPUTER VISION, PHOTOGRAMMETRY, SURVEY,

Abstract:

The proposed research project aims to improve the efficiency, interpretation and processing workflow of 3D/2D data acquired from surveying, in terms of reduction of processing time, computerization and optimization of the final products, through the application of Artificial Intelligence (AI), for the automated structuring, recognition and/or segmentation of relevant cultural heritage data, starting from 3D laser scanners or photogrammetric surveys. Many of the datasets and surveys we encounter may have several critical issues that need to be addressed depending on the type of object we need to return (especially regarding the Cultural Heritage).Specifically, standard SfM softwares many times fails to capture and retain information of reflectivity, transparency, homogeneous textures, non-Lambertian surfaces, regarding a large number of artefacts. In recent years much research has been dwelling on this problem, trying to use Computer Vision (CV) and Artificial Intelligence (AI) integrated with standard photogrammetry to improve and obtain good 3D models of these particular objects or scenes. e.g. Neural Radiance Fields or 3D Gaussian-Splattting. In this first presentation i will present a first approach and an hybrid methodology that links AI and CV-based softwares with the standard photogrammetry.

A novel integrated transport-territory modelling approach

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Doctorate Thesis: A new integrated transport/territory planning process to make conurbations sustainable by achieving carbon neutrality, zero pollution and environmental resilience

Keywords: Transport planning, multidisciplinary approach, 4-stage model, Agent Based model, Activity Based model, Travel diaries, Urban sustainability

Abstract:

Transport planning is a key point in the creation of sustainable urban agglomerations from multiple points of view. However, the models currently used in transport simulations, especially the traditional 4-stage model, only take into account a part of the variables that modify or could modify the demand for mobility. A multidisciplinary and integrated approach is therefore necessary, increasingly introducing, for example, the social, economic and territorial dimension in simulation studies. In this way it will be possible to obtain a truthful representation of human behaviour, and of the factors that influence it. This is particularly true in relation to the fact that the transport choices of individual users are not defined exclusively by socioeconomic conditions or by the offer and services provided, but also by exclusively personal variables that are often hidden or not considered. The models obtained will allow to evaluate the policies to be implemented in urban and rural areas, providing policy makers and institutions with feedback for the most effective choice for each reality.

Variational study of tape springs

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Doctorate Thesis: Variational deduction of 1D models for tape spring devices

Keywords: energy, 1D model, non-convex, stationary points, minimizers, concentration of curvature

Abstract:

Here there is a short introduction to tape springs, and a presentation of a variational study of this devices that we made. Starting from the work of Picault et al. (A rod model with thin-walled flexible cross-section: Extension to 3D motions and application to 3D foldings of tape springs, 2016) we derived a one dimensional model, by variational approach, in the case of the device behaves constantly along the center line. As a result the diagram of the energy vs the longitudinal curvature is non convex. Having in mind this result and the results of numerical simulations we assumed a simplified non-convex behavior for the energy density of the 1D model. To this energy corresponds a bending moment, that is the slope of the energy function, that isn't continuos. We studied the stationary points and the minimizers of the energy, and we show that the device is subjected to concentration of curvature.

Microplastic Dispersion Model from the Arno River to the Tuscan Archipelago and the Ligurian Sea

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Doctorate Thesis: High-Resolution Modeling of Microplastic Dispersion in the Northwestern Mediterranean: Oceanographic Dynamics and Environmental Impacts

Keywords: Microplastics, Modelling, Dispersion, River Mouth

Abstract:

The dispersion of microplastics in aquatic environments is a serious threat to marine ecosystems, particularly in the Mediterranean Sea. Due to its semi-enclosed nature and high population density along its coasts, river mouths such as the Arno are significant sources of plastic pollution. Numerical modeling in this area is still underdeveloped compared to field measurements. This study aims to: develop a microplastic dispersion model specific to the Tuscan Archipelago and Ligurian Sea, focusing on major river mouths in Tuscany, identify the distribution patterns of microplastics and their variations based on hydraulic conditions and particle characteristics like size, density, and composition. The model integrates two systems: ROMS, a 3D hydrodynamic model, and LTRANS, a Lagrangian particle-tracking model. Different scenarios were tested, considering turbulence, river flow variability, and particle sedimentation. The study has already conducted field measurements in the Arno River and surrounding areas, with further campaigns planned. The results show that the coupled model is a powerful tool for predicting the transport and fate of microplastics in the marine environment. The inclusion of sedimentation highlights its influence on particle dispersion. The next step in this analysis will involve applying a high-resolution model on a larger scale like as the whole North-West Mediterranean Sea, combined with inverse modeling (tracing from concentration back to the source) to achieve a more detailed characterization of the model using field data.

Innovative management tools to increase the resilience of public buildings against natural risks

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Doctorate Thesis: Innovative management tools to increase the resilience of public buildings against natural risks

Keywords: Natural Hazards, Built Environment, Digital Building Logbooks, Climate Change

Abstract:

Natural hazards represent a major threat for people, property, environment, and cultural heritage. In the coming decades, the EU is expecting to experience more extreme events that will have an impact on the built environment. This sector is particularly at risk due to the potential historical and economics losses. Therefore, procedure to assess the vulnerability of existing buildings and define adaptation strategies are needed to increase their reliability and resilience against natural hazards. A methodology of risk analysis for buildings to extreme events, based on data collected in innovative Digital Building Logbooks, is in development. In fact, the current research about DBLs is making available a lot of digitised information in a common environment enabling also the development of tools to assess the buildings vulnerability to natural extreme events. This assessment, combined with other performance indicators, will allow entities with many properties (company or public authority) to define the priority of interventions when they deal with a large population of buildings. The benefits of using DBLs to collect and manage information could be the solution for planning adaptation measures for built environment in response to climate change impacts.

Adaptation of coastal defenses in climate change scenarios: A review on protective gravel nourishment

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Doctorate Thesis: Artificial Gravel and Pebble Beach Nourishment: A Nature-Based Solution for Flood Control in Low-Lying Coastal Areas Under Climate Change Scenarios

Keywords: Gravel nourishment, dynamic cobble berm revetments, coastal protection

Abstract:

Coastal areas are currently experiencing unprecedented amounts of natural and anthropic pressure, as 80% of beaches are estimated to be eroding. This exposes the coast to two main hazards, flooding, and erosion. The use of hard coastal protective structures (breakwaters, seawalls, groynes), is progressively being complemented by softer strategies (e.g. beach nourishment) and lately by "design with nature" concepts. The use of gravel structures has recently been widely accepted as a form of soft shore protection as it keeps the economic and natural value of beaches compared to hard structures, while carrying the potential for coastal protection. The concept of "design with nature" was accepted in dynamic cobble berm revetments, but there is still a lack of design knowledge. These dynamic revetments involve the addition of large volumes of coarse gravel sediments on the existing beach, often sandy beaches. The dynamicity of this environment results in a sediment matrix that is variable over time and directly impacts the efficiency of the revetment in energy absorption. The sand and gravel interface of the revetment varies greatly through accretion and erosion phases on the underlying sand and is essential for its protective behavior, but these dynamics are understudied and need to be further understood for successful protective designs. In this context, this research aims to understand and predict erosion and accretion of sand and analyze how that impacts the behavior of revetment in runup and overwash, based on the toe's position regarding m.s.l. and slope thickness, through experimental modelling.

Assessing the Impact of Aging Conditions on the Performance of Bio-Binder

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Doctorate Thesis: Investigation of the effects of different aging conditions on the chemical, rheological and molecular properties of bio-binder

Keywords: Aging, Bio-binder, MD Simulation, Rheology, Microstructure morphology.

Abstract:

This presentation focuses on a project that investigates the effects of various aging factors on bio-bitumen to assess their impact on rheological, chemical, and physiochemical properties. Since aging significantly influences the performance of bio-bitumen, and therefore pavement, improving the simulation method by incorporating different factors will provide a more accurate prediction of bio-bitumen's long-term behavior. To address these challenges, the project employs more precise approaches for simulation and evaluation of aging. In this presentation, the current literature on aging simulation and evaluation, initial findings concerning rheological properties and finally employed methodologies, and desired aims will be presented. The preliminary findings illustrate that in the simulation phase of aging, despite the attempts made to implement affecting external factors in aging simulation, there is still little focus on using various factors in the laboratory aging process. Regarding the evaluation test methods both on the rheological and chemical point of views, different testing methods and analysis procedures are commonly used, but still certain aspects could and need to be improved. Additionally, the initial laboratory results for conventional aging methods, without considering various factors, indicate that the rheological properties of bio-bitumen can be affected. Therefore, future work will focus on integrating overlooked factors to achieve a more accurate simulation and evaluation.

Assessment of the seismic behavior of historical churches: a multidisciplinary analysis of the parish churches

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Doctorate Thesis: INNOVATIVE METHODS FOR THE DOCUMENTATION AND PRESERVATION OF THE PARISH CHURCHES OF LUNIGIANA

Keywords: Multidisciplinary approach, Seismic vulnerability, Collapse mechanisms, Digital surveying

Abstract:

Earthquakes represent one of the most significant risks for historical buildings, particularly for masonry churches, which are inherently vulnerable to seismic action. Horizontal stresses generate tensile and shear forces that exceed the material's limited resistance. Initial observations on church damage, starting with Doglioni et al. (1994) after the 1976 Friuli earthquake, indicated that churches' seismic behavior is influenced by recurring failure mechanisms, with an almost independent behavior of the structural macro-elements. This research examines 35 parish churches (pievi) of the ancient Diocese of Luni, initially gathering data on damage mechanisms and the vulnerability of both the macro-elements and the entire structure. The structural analysis of these churches is framed within a multidisciplinary context, based on an in-depth understanding of their history (transformations, traumatic events, interventions), critical surveying (geometry, construction technology), material characteristics and deterioration, and the assessment of crack and deformation patterns. Part of the data comes from institutions and archives involved in heritage management (Diocese, CEI, INGV, Region, etc.). The parish churches were mapped in QGIS and divided into two categories (simple and complex). The activated and potentially activatable collapse mechanisms for each category are analyzed to identify the main vulnerabilities for each category, determine the parameters to be collected, and select the most suitable digital technology. The methodological approach integrates digital surveying to create a 3D model, enabling the acquisition of georeferenced and dimensional data, the identification of structural weaknesses, the extent of deterioration, and past interventions.

Identification of Climate Change Induced Modification in Directional Wave Spectrum

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Doctorate Thesis: Identification of Climate Change Induced Modification in Directional Wave Spectrumication in

Keywords: Wave Spectrum, Climate Change, Wave Direction

Abstract:

This research explores the impact of climate change on the directional wave spectrum, focusing on changes in wave characteristics driven by evolving climatic conditions. By analyzing long-term satellite and buoy data from various oceanic regions, we examine trends in wave height, direction, and energy distribution. The findings reveal significant changes in the wave spectrum, including increased energy at specific frequency bands and shifts in wave directionality. These modifications may affect coastal ecosystems, maritime navigation, and coastal infrastructure resilience. This study contributes to a deeper understanding of climate-induced changes in oceanic processes and emphasizes the need for adaptive management strategies to mitigate impacts on marine environments.

Quantitative assessment of seismic risk for built heritage structures

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Doctorate Thesis: Quantitative assessment of seismic risk for built heritage structures

Keywords: Cultural heritage, Vulnerability, Seismic risk

Abstract:
Preserving cultural heritage buildings and monuments which have outstanding universal value and connection with communities, is crucial for future generations. Cultural heritage assets are increasingly threatened by natural hazards. Particularly earthquakes because of the unpredictability of the exact occurrence, intensity, and time. Based on recent earthquakes all over the world, the physical vulnerability of built heritage is mainly due to the large presence of unreinforced masonry buildings each with a specific structure. National and international authorities around the world have highlighted the urgent need to integrate the specific characteristics of cultural heritage assets into disaster risk reduction plans. To define strategic mitigation plans, estimating the effects of an earthquake on heritage buildings is essential. Defining prioritization schemes and strategies for resilience-enhancing can be achieved using quantitative risk assessment of building portfolios in earthquake-prone regions. The research focuses on the seismic risk assessment of cultural heritage assets to develop a quantitative seismic risk prioritization framework for the derivation of vulnerability curves that integrate both tangible and intangible values of cultural heritage assets. Five key components of the project can sum up: creating a taxonomy of cultural heritage assets, analyzing fragility through numerical models, calibrating damage-to-loss functions with historical data, incorporating intangible values, and developing comprehensive vulnerability curves. This project also provides practical criteria for designing disaster risk reduction policies on cultural heritage portfolios.

Assessment of the seismic behavior of historical churches: a multidisciplinary analysis of the parish churches

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Doctorate Cycle: XXXIX

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Supervisors: Barbara Pintucchi, Valentina Bonora

Doctorate Thesis: INNOVATIVE METHODS FOR THE DOCUMENTATION AND PRESERVATION OF THE PARISH CHURCHES OF LUNIGIANA

Keywords: Multidisciplinary approach, Seismic vulnerability, Collapse mechanisms, Digital surveying

Abstract:

Earthquakes represent one of the most significant risks for historic buildings, especially masonry churches that show little connection between their structural elements. Initial observations on church damage, starting with Doglioni et al. (1994) after the 1976 Friuli earthquake, indicated that churches' seismic behavior is influenced by recurring failure mechanisms, with an almost independent behavior of the structural macro-elements. This research examines 35 parish churches (pievi) of the ancient Diocese of Luni, initially gathering data on damage mechanisms and the vulnerability of both the macro-elements and the entire structure. The structural analysis of these churches is framed within a multidisciplinary context, based on an in-depth understanding of their history (transformations, traumatic events, interventions), critical surveying (geometry, construction technology), material characteristics and deterioration, and the assessment of crack and deformation patterns. Part of the data comes from institutions and archives involved in heritage management (Diocese, CEI, INGV, Region, etc.). A GIS project maps churches and makes it possible to organise a heterogeneous amount of information about them, highlighting the importance of georeferencing data and supporting a first attempt to categorise them. For each church, the activated and potentially activatable collapse mechanisms are analysed, to identify the main vulnerabilities for each category, determining the parameters to be collected, and selecting the most suitable digital technology. The methodological approach explores quick and low-cost digital surveying to create a 3D model, allowing for the acquisition of dimensional data, which is useful for identifying structural weaknesses, the extent of deterioration, and past interventions.

Advancing Seismic Site Response Analysis: Boundary Condition Optimization and Integrating Approach with Machine Learning

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Doctorate Thesis: Formulation and calibration of seismic code-format approaches to the estimation of seismic basin effects through non-deterministic numerical geotechnical seismic site response analysis and machine learning-based metamodeling

Keywords: Basin effects, Dynamic boundary conditions, Machine learning, OpenSees, Parametric study, Seismic site response analysis

Abstract:

Modeling ground response is crucial for seismic site response analysis (SRA), particularly in complex stratigraphic and morphological environments. In such contexts, a continuum-based analysis is necessary to accurately capture the conditions. Boundary conditions (BC) play a pivotal role, enabling realistic simulations of seismic wave propagation. This presentation outlines preliminary findings from broader research aimed at developing computational approaches for quantifying SRA in basins. A comparative SRA in the time and frequency domains is conducted on a two-dimensional basin model using OpenSees, focusing on different BC modeling approaches under dynamic loading (equal degrees of freedom, Lysmer and Kuhlemeyer viscous absorbers, massive boundary columns, and free-field boundary columns). The contents of this presentation will be published as a conference paper. Meanwhile, the impact of BC modeling properties, such as column width, is also being investigated using different BC methods. Although limited in scope and generality, these results highlight the sensitivity of response outputs to the approach adopted in BC modeling and provide valuable preliminary evidence about the merits, drawbacks, and applicability of the considered approaches. To enhance future meta-modeling of SRA, a suite of Python scripts has been automated to accommodate diverse BC methods, modeling properties (e.g., geometric and geotechnical), and various seismic inputs.

From Seaweed to BioExtender

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Doctorate Thesis: Sviluppo di biomateriali e leganti bio-circolari carbon neutral ad alte prestazioni per applicazioni in campo stradale

Keywords: Biobitumen, Seaweed, Orbetello Lagoon, HTL

Abstract:
At the start of this study, an extensive literature review was conducted to identify potential biomasses for use as bio-extenders. The criteria included their abundance in nature, lack of alternative reuse, and the ability to produce a product with chemical-physical properties comparable to bitumen through an environmentally and industrially sustainable process. A mix of algae from the Orbetello Lagoon was selected for analysis, as recent changes in the lagoon's vegetation, driven by the Albegna River's fertilizer runoff, have increased algal growth. On February 2, 2024, algae were collected in collaboration with the Municipality of Orbetello and local experts. The samples were washed, dried at 40°C for 9 days, and ground to 300 µm. Soxhlet extraction was performed using solvents (dichloromethane, toluene, and hexane) on fresh, dried, and lyophilized samples with various pretreatments. The highest oil yield (13%) was achieved with toluene, although this is still insufficient for bio-extender use. Soxhlet extraction is energy-intensive, requiring significant amounts of water and energy to heat and condense the solvent. Additionally, a rotary evaporator was used to recover and concentrate the oil. The defatted algal substrate is currently being studied in collaboration with the University of Naples for biopolymer production. To enhance oil yield, hydrothermal liquefaction (HTL) was explored. This process promotes the depolymerization of cellulose and lignin, abundant in algae, to increase bio-oil output. Ongoing research, in partnership with Prof. Rosi from the University of Florence, aims to optimize the HTL process parameters to maximize liquid phase yield and characterization.

Definition of Informed Digital Twins to Optimise the Maintenance and Renovation of the Public Buildings

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Doctorate Thesis: Definition of Informed Digital Twins to Optimise the Maintenance and Renovation of the Public Buildings

Keywords: Structural Health Monitoring, Digital Building Logbook, Digital Twin, Cultural Heritage, Uncertainty Quantification

Abstract:

Balancing the preservation of the historical and cultural significance of the built environment with compliance to recent EU directives on resilience, sustainability, and energy efficiency in the building sector is a key challenge for Europe. In the field of heritage conservation, the integration of digital tools has transformed the approach to management, maintenance and renovation of existing building stock. Digital Building Logbooks (DBLs) and Digital Twin (DT) technologies have the potential to support the assessment and the monitoring of structural performance, in order to identify vulnerability and to enable better decision making throughout the building lifespan. In this presentation, a framework is proposed for developing structural DTs to monitor the dynamic behavior of heritage buildings. The framework initiates with data gathered from DBLs and encompasses the generation of Heritage Building Information Models (H-BIM) derived from digital surveys. Subsequently, three-dimensional finite element models (FEM) are generated and calibrated using sensor data. This approach addresses the challenges associated with interoperability, particularly those related to the reproduction of complex geometries, the assignment of material properties and the generation of accurate shells. A Polynomial Chaos Expansion-based surrogate model will be constructed with the objective of providing an analytical representation of the dynamic response and of reducing the computational burden associated with the probabilistic framing of the updating problem. The proposed methodology will be illustrated with reference to a significant case study, Palazzo Poniatowski-Guadagni, a 18th-century masonry building in Florence. The resulting digital twin will be integrated into the BUILDCHAIN system (https://buildchain-project.eu/), which seeks to

illustrate the advantages of utilising innovative digital building logbooks for the effective management and preservation of cultural heritage.