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Supervisor Expression of Interest
MSCA - Marie Sklodowska Curie Action - (PF) Postdoctoral Fellowship 2024

Supervisor name: Liberato Ferrara

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Link "Pagina docente":
https://www8.ceda.polimi.it/manifesti/manifesti/controller/ricerche/RicercaPerDocenti.do?jaf_currentWFID=main&EVN_DIDATTICA=evento&aa=2023&k_doc=64974&lang=IT
Department Name: Civil and Environmental Engineering

Research topic: Additive manufacturing with non conventional construction materials

MSCA-PF Research Area Panels:

- ☐ ECO_Economic Sciences
- X ENG_Information Science and Engineering
- ☐ ENV_Environmental and Geosciences
- ☐ LIF_Life Sciences
- ☐ MAT_Mathematics
- ☐ PHY_Physics
- ☐ SOC_Social Sciences and Humanities
- ☐ CHE_Chemistry

Brief description of the Department and Research Group (including URL if applicable):

The research group is led by the supervisor (prof. L. Ferrara, full professor), in collaboration with two assistant professors (dr. E. Cuenca and dr. F. Lo Monte) and currently one MSCA-IF post-doctoral student (plus one starting early 2025) and thirteen PhD students (two are joint PhD students with University of Gent, with either institution as a host, four about to graduate). Collaboration is active also with research group led by prof. G. Muciaccia (three co-supervised PhD students) and prof. M. Cremonesi (one co-supervised PhD student).
The group is active in research, teaching and service in the broad fields of concrete and advanced cement based materials and fabrication processes, including robotics, with documented activities and experience covering several aspects of the proposal. The group has performed top-notch research in the fields of: advanced cement-based materials concept and technology; experimental characterization of their mechanical properties, also under extreme conditions, including, e.g., earthquake, fire, fatigue, impact or extreme environmental exposure; advanced multi-scale

characterization of cementitious materials and non-destructive characterization of fibre reinforced concrete meso-structures, including fibre dispersion/orientation with electrical resistivity and magnetic inductance based methods; material durability, with analysis of degradation processes and of self-healing autogenous and engineered mechanisms; interaction with steel and polymer reinforcement, including corrosion; structural applications and design methods; multi-scale and multi-physics modelling including hydration, fracture, damage and degradation processes; computational fluid dynamics modelling of fresh concrete behaviour and 3Dconcrete printing processes, and circular economy in construction industry.
The supervisor is active in international scientific and technical organization within RILEM, *fib* and ACI, in technical committees addressing technology transfer and standardization in different fields of his research activity and is author of more than 100 papers in peer reviewed journals (with more than 5000 citations - h-index 38 as per Scopus)

The supervisor has documented coordination and leadership experience in the field of Marie Curie Personal Fellowships, being
•**Supervisor of individual Marie Slodowska Curie individual post-doctoral fellowship AESTHESIS – 101109186 "Innovative multifunctional retrofitting systems for heritage structures"** (2024-2026). Total grant 175 k€.
•(upcoming) **Supervisor of individual Marie Slodowska Curie individual post-doctoral fellowship InCreeGuing – 101149607 "Untying the knot of creep and fatigue behaviour of UHPC for sustainable design of infrastructures enabling the carbon neutrality transition"** (2025-2027). Total grant 175 k€.
as well as in international projects and consortia. He is/has been:
- • Coordinator of Horizon 2020 project ReSHEALience (GA 760824) – "Rethinking coastal defence and green Energy Service infrastructures through enHancEd durAbility high-performance fiber reinforced cement based materials". www.uhdc.eu (total grant 5.5 M€ - PoliMi share 600 k€).
The project (2018-2022) has delivered, as an outcome of the materials and design methodologies developed, six TRL7 full scale pilots in ultra-high performance fibre reinforced cementitious composites exposed to aggressive environments, ranging from offshore wind tower floaters, aquaculture rafts and harbour facilities to geothermal power plant infrastructures to the retrofitting of an existing water tower in airborne chloride rich environment.
•Deputy coordinator of MSCA-ITN SMARTINCS (GA 860006) – "Self-healing multifunctional advanced repair technologies in cementitious systems" - www.smartincs.ugent.be (total grant 4 M€ - PoliMi share 300 k€) (2019-2024).
The project is training 15 PhD students in the topics of prevention of deterioration of new concrete infrastructure by innovative, multifunctional self-healing strategies and existing concrete infrastructure by advanced monitoring and repair technologies.
•Co-PI and WP leader in EC RFCS (Research Fund for Coal and Steel) project MINRESCUE (GA 899518) – " From Mining Waste to Valuable Resource: New Concepts for a Circular Economy " www.minrescue.gig.eu (total grant 3.2 M€ - PoliMi share 300 k€) (2020-2024).
The core objective of the project is to develop and validate a strategy to upgrade CMWGs as constituents in sustainable construction materials and products, contributing to the establishment of a circular economy in coal mining areas.

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•Co-Pi and department research group leader in MUSA- Multilayered Urban Sustainability Action (2022-2026) – Italian National Plan of Recovery and Resilience.

The research group got a funding of 400 k€ and will be involved in Spoke 3 of the project "Deep Tech: Entrepreneurship & Technology Transfer" and will work on the development of concrete 3Dprinting/additive manufacturing as a Key enabling Technology to promote the use of advanced cement based materials for topologically optimized structures, aimed at the reduction of the overall carbon footprint (material-product-process).

•Co-Pi in BRIC-INAIL project (funding agency INAIL Italian National Institute for Work Safety Insurance) – "NORMA: Naturally Occurring Radioactive Materials Activities. Scientific, technological, social and economic strategies to implement radioprotection measures in circular economy uptake of NORM" (total grant 560 k€ – PoliMi share 125 k€) (2023-2024).

The group is also active in fundraising and healthy technology transfer cooperation with major industrial players in the field of concrete construction industry:

2022-2023: Fatigue behaviour of Ultra High Performance Concrete – CEMEX – 145 k€

2022-2023: Optimization of cementitious mixture for additive manufacturing of reinforced concrete tunnels – Hinfra – 100 k€.

2022-2023: Optimization of the structural design of FRC frame structures under static and fatigue loading– Energy Vault – 80 k€

2022: Optimization of mix-design, rheological and mechanical properties of UHPC for double curvature shells – RIMOND – 35 k€.

2021-2022: Experimental campaign for the characterization at the fresh and hardened state of cementitious composites with irradiated plastic waste particles – JRC EC – 15 k€

2024: accelerated carbonation of cementitious materials via CO_2 sequestration – SIMEM- 7k€

2024: Valorization of electric arc steel slag in concrete manufacturing – Tenova 10k€

2024-2027: Valorization of municipal solid waste ash and waste from steel production as a carbon sink secondary raw material in concrete production – Resilco 45 k€

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TITLE of the project: "Innovative BeyondTheEarth Construction: Utilizing 3D Printing with Hydrogel-Infused Regolith for Lunar and Martian Structures"

Brief project description:

The exploration and colonization of extraterrestrial bodies including the Moon and Mars require innovative construction techniques tailored to the unique environments of these celestial bodies. Traditional construction methods and materials are impractical due to the high cost of transportation from Earth. In-situ resource utilization (ISRU) presents a viable solution by using local materials for construction.
This proposal focuses on the development of a 3D printable material using lunar or Martian regolith with hydrogels as binder, aiming to provide a solution for building infrastructure at the initial stage of landing the Moon or Mars. Hydrogel represents a class of cross-linked polymer that can retain high water content and then subsequently harden upon drying or freezing. When used as a lunar or Martian concrete binder, it can efficiently engage the H2O in situ (there are vast ice caps on Mars's surface) and provides feasibility for 3D printing construction without the need for laser sintering or other energy-intensive facilities. This is particularly advantageous in the early stages of establishing a base on the Moon or Mars, where resources and energy are limited. Distinct from previous space concrete formulations that utilize basalt (comprising oxides of silicon, calcium, aluminum, and iron) or pure sulfur as binders, HBC offers a promising alternative. Its utilization could significantly streamline the process of building foundational infrastructure on these celestial bodies, marking a critical step forward in human space exploration and habitation.

Objectives:

1. To develop a composite material by integrating hydrogel with Lunar or Martian regolith, optimizing for structural stability, resilience, and environmental suitability.
2. To investigate the rheological properties of the hydrogel-regolith composite at its fresh state with a focus on its suitability and pumpability.
3. To research the mechanical properties of the printed composite, including its compressive strength, tensile strength, and flexibility under simulated lunar and Martian conditions.

Expected Outcomes:

- A comprehensive understanding of the mechanical and environmental performance of hydrogel-regolith composites and definition of a performance based fabrication approach.
- Guidelines for the design and construction of structures on the Moon and Mars using this novel material.