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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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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: Circular economy and Structural Design

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

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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: " Optimisation of the material safety factor and sensitivity analysis of the key parameters in the shear design of the reinforced recycled aggregate concrete beams "

Brief project description:

With the escalating demand for infrastructure development on one hand and the challenge of construction and demolition waste disposal on the other, the utilisation of recycled aggregates (RA) has become imperative. While most codes were previously silent on the inclusion of RA, they have recently begun to provide regulations regarding its use. However, the guidelines for calculations of the structural capacity under serviceability and ultimate limit states are not yet specifically tailored for Recycled Aggregate Concrete (RAC). Moreover, existing literature indicates inconsistent performance of RAC structural elements, especially when it come to shear. Therefore, to facilitate the integration of RA into construction projects and prevent potential structural failures leading to loss of life, a comprehensive understanding of its behaviour in brittle failure modes like shear is crucial. The objective of this study is to address this design challenge by offering two solutions. Firstly, key parameters influencing structural capacity under different stress states and their respective significance will be identified to enable better control in determining the mix design of Recycled Aggregate Concrete, as a function also of the properties of the RCA, and the outcomes in terms of structural performance. AI tools will be also utilized for multi-performance multi-scale performance analysis and correlation. The design outcome in terms the material factor of safety, as per *fib,* Eurocode and ACI standards, will be adjusted for RCA to enhance the prediction of the structural capacity.

Objectives

While the main objective of the proposed study is to optimise the safety factor suitable for the shear design of recycled aggregate concrete (RAC) beams with and without shear reinforcement and identify the key parameters effecting the shear capacity, the specific objectives are:

1. Create a database of the structural capacity of RAC structural elements by performing experiments using RCA from different sources (3 to 4) and 4 varying matrix strength as well as from the available literature. Advanced measurement techniques, including DIC, will be employed to capture the mesostructural mechanisms and correlate with the properties at the material level.
2. Compare the dataset with structural capacity according to the Euro code and ACI to determine the adjustments required in the material safety factor in the codal provisions to predict the shear capacity of RAC beams with 95% confidence.
3. Select probable key parameters from the analysis of experimental data influencing the shear capacity the most.
4. Determine the weight of each parameter

Methodology

1. Flexural-shear tests will be performed on reinforcement concrete beams of different grades cast with RCA from 3 to 4 different sources.
2. A data set will be created from the experimental program as well as available literature.
3. Shear capacity according to the *fib,* Eurocode and ACI will be compared using curve fitting to determine the required material safety factor for RAC.
4. Figure out the probable key parameters influencing the flexural and shear capacity from the variation in experimental data.
5. Perform sensitivity analysis to determine the weight of each parameter.

Expected Outcomes

1. Achieving the required material safety factor for RAC beams subjected to flexural shear.
2. Figuring out the key parameters influencing the flexural-shear capacity of the reinforced RCA beams with their corresponding weight.