Information about the Research Programme and topic

in the framework of the Italian National Recovery and Resilience Plan (PNRR 2021)

founded by European Commission, NextGeneration EU programme

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

PhD Research Topic

Ongoing climatic changes have increased the frequency and magnitude of synoptic wind storms in extra-tropical regions, Europe included. Vaia (26-30 Oct 2018, Italian Dolomites, gusts up to 200 km/h), Ciara (3-16 Feb 2020, United Kingdom and Ireland, gusts up to 160 km/h), and Odette (23-26 Sept 2020, Belgian coasts, gusts over 100 km/h) are recent and harmful examples of such European wind storms.

Vaia storm (2018): effects on forests

Odette storm (2020): effects on coasts

Ciara storm (2020): effects on buildings

Such events impact on both built environment and human activities (e.g. transport and energy infrastructures, buildings, urban areas), and natural environment (e.g. forests, coastal dunes). Windstorms were respectively the first and fourth natural hazard in Europe between 1980 and 2015 causing economic losses and human casualties, respectively. For instance, Ciara involved 17 fatalities, and about 1.9 b€ in damages, while Vaia caused 8 fatalities, 2.8 b€ in damages, and 42 million of fallen trees over 41,000 hectares of forest.

Wind induced disasters are directly induced by the wind itself, or by wind-induced phenomena, such as windblown sand or flying debris. Both coastal and inland zones are threatened. Coastal zones are particularly exposed to extreme wind events inducing sand transport and detrimental effects on urban environment. Poor management of natural ecosystems increases the vulnerability of inland zones, such as forests and urban areas.

The project generally aims at learning lessons from the past events, and mitigating the vulnerability of exposed systems through the conceptual design of natural and/or bio-inspired Mitigation Measures (MM). In particular, the project is addressed to porous belts to be deployed around/along the exposed system, made by plants and/or trees and/or man-made porous barriers. The sheltering performances of the conceived MM(s) will be assessed under different environmental and operational conditions. Performances will be optimized by means of machine learning techniques, e.g. genetic algorithms.

Both performance assessment and optimization will be supported by an efficient computational model of the turbulent wind flow in the Atmospheric Boundary Layer through porous obstacles. The equivalent aerodynamic porosity of the vegetated belt will be evaluated in statistical terms from observations of real-world plants and/or trees. The mathematical model will be solved by means of computational engineering simulations.

Keywords
Wind Storms; Natural and built environment; Mitigation Measures design; Computational Simulation

ERC Sectors
PE8_3 - Civil engineering, architecture, offshore construction, lightweight construction, geotechnics
PE8_5 - Fluid mechanics
PE8_4 – Computational Engineering

Information about the Research Team

Academic Tutors
- Luca Bruno, full professor in Structural Engineering, specializing in Wind Engineering - Department of Architecture and Design (luca.bruno@polito.it);
- Luigi Preziosi, full professor of Mathematical Physics, specializing in multiphase flows and porous media mechanics – Department of Mathematical Sciences (luigi.preziosi@polito.it);
- Lorenzo Raffaele, researcher in Structural Engineering, specializing in windblown sand action – Department of Architecture and Design (lorenzo.raffaele@polito.it).

Research Environment
The Departments of Architecture and Design (DAD) and of Mathematical Sciences (DISMA) of Politecnico di Torino ensure the complementary and interdisciplinary competences needed to achieve the objectives of the project.
The members above widely collaborated in the last 10 years in scientific fields relevant to or related to the proposed research topic, as testified by the lists of selected publications, research outputs, research projects and impact activities relevant to the topic of the project.
Politecnico di Torino will deploy the computational resources required by the project, thanks to the HPC Academic Computing center (www.hpc.polito.it), that offers more than 3000 computational cores over three InfiniBand clusters.

Selected relevant publications
1. M. Horvat, L. Bruno, S. Khris, L. Raffaele (2020) Aerodynamic shape optimization of barriers for windblown sand mitigation using CFD analysis, Journal of Wind Engineering & Industrial Aerodynamics 197, 104058
2. L. Raffaele, L. Bruno (2019) Windblown sand action on civil structures: Definition and probabilistic modelling, Engineering Structures, 178, 88-101
3. L. Bruno, M. Horvat, L. Raffaele (2018) Windblown Sand along Railway Infrastructures: A review of Challenges and Mitigation Measures, Journal of Wind Engineering & Industrial Aerodynamics, 177, 340-365
4. L. Raffaele, L. Bruno, D. Fransos, F. Pellerey (2017) Incoming windblown sand drift to civil structures: a probabilistic evaluation, Journal of Wind Engineering & Industrial Aerodynamics, 166, 37-47

5. L. Preziosi, D. Fransos, L. Bruno (2015) A Multiphase First Order Model for Non-Equilibrium Sand Erosion, Transport and Sedimentation, Applied Mathematical Letters 45, 69-75

Selected relevant research outputs

1. 2013: scientific and technical consultancy for the designer in charge of the preliminary design, detailed design, and performance assessment of Windblown Sand Mitigation Measures along the 900 km-long Saudi Landbridge railway line, Kingdom of Saudi Arabia.
2. 2015: L. Bruno, L. Preziosi, D. Fransos, Invention of an innovative, highly efficient, Windblown Sand Mitigation Barrier. Patent number WO 2016/181417 A1 "A deflecting module for an anti-sand barrier, a barrier thus obtained and a protection method from windblown sand". Patent owned by Politecnico di Torino. Commercialization in charge of the Research Support and Technology Transfer Department (TRIN).
3. 2014 – present: scientific and technical consultancy in charge of the analysis of incoming windblown sand drift and design of sand mitigation measures along railway lines in Oman, UAE, Egypt.
4. 2019 – present: scientific and technical consultancy in charge of the analysis of incoming windblown sand drift and design of sand mitigation measures along acid pipelines (Kazakhstan), and around solar power plants (UAE).
5. 2009 – present: Benchmark on the Aerodynamics of a Rectangular 5:1 Cylinder (BARC, www.aniv-iawe.org/barc-home), an open access fundamental benchmark on wind effects on bluff bodies.

Selected relevant research projects

1. 2016-2017: "Shield for Sand" (S4S) project, part of the Proof of Concept R&D programme at Politecnico di Torino. Funding source: Compagnia di San Paolo. Number of years: 1. Role of the reference person: PI of the project. Wind Tunnel tests on a scaled model of a windblown sand mitigation measure at Von Karman Institute for Fluid Dynamics (Sint-Genesius-Rode, Belgium).
2. 2017-2020: H2020/MSCA/ITN/EID project Sand Mitigation along Railway Tracks (SMaRT, www.smart-eid.eu, grant agreement No 721798). Funding source: European Research Agency. Number of years: 4. Role of the reference person: PI and Scientific Coordinator of the whole consortium.
3. 2019-2021: H2020/MSCA/IF project **Hy**brid **Per**formance Assessment of **S**and **M**itigation **M**easures (HyPer SMM, www.hypersmm.vki.ac.be) Funding source: European Research Agency. Number of years: 2. Lorenzo Raffaele, member of the PRO Wind research team, has been the Principal Investigator of the project.
4. 2022-2024: **PRO**tection **T**echnologies from **E**olian **E**vents for **C**oastal **T**erritories (PROTEECT, www.proteect.polito.it). Funding source: Italian Ministry for University and Research (PON-FESR, 66%), Reference person (33%). Number of years: 3. Role of the reference person: Scientific Coordinator.

Relevant Impact

1. 2014 – present: co-founders and coordinators of the Windblown Sand Modelling and Mitigation (WSMM, www.polito.it/wsmm) multidisciplinary, international and intersectoral research, development and consulting group jointly established by Politecnico di Torino (Department of Architecture and Design, Department of Mathematical Sciences) and Optiflow Company (Marseille, France).

2. 2016: newspaper article on La Stampa - national edition March 9th 2016 "Gioca col vento e vince la sabbia: il super-treno del deserto", and in the newpaper on ResearchItaly, web portal of Ministry of Education, Universities and Research (MIUR), section Projects & Success Stories "A railway in the sand" (https://www.researchitaly.it/en/understanding/project-and-success-stories/success-stories/a-railway-in-the-sand/).
3. 2019: invited key note talk (title of the lecture: “Adverse weather resilience: prepare and protect”) at Middle East Rail 2019 Expo and Conference, Dubai, February 26th -27th 2019. Middle East Rail is the referential event on railway industry in Middle East North Africa region, organized under the patronage of the Ministry of Infrastructure and Development Federal Transport Authority - Land and Maritime, United Arab Emirates.
4. June 2018 and July 2019: newspaper articles "A SMaRT approach to sand mitigation" on Railway Gazette International (the international leading source of technical news and business information for the global railway industry) and “Solving the sand issue” on Railways Africa Magazine (the African continent's specialist trade, technical, business-to-business publication, and online news service covering all aspects of the rail sector).
5. 2019 – present: the Luca Bruno is President of the Italian Association for Wind Engineering (ANIV, www.aniv-iawe.org).

Information about the required profile

The PhD - Early Stage Researcher (ESR) shall carry out the design of the mitigation measures, and their performance assessment. The ESR shall pursue the above activities by adopting a multiphysics modelling that includes wind fluid dynamics, porous mechanics, wind effects on natural and man-built structures, and by computational simulations.

In order to successfully conduct the activities above, both hard and soft skills are required.

Hard skills: An ideal PhD candidate will hold a Master’s degree and have excellent marks from his/her previous studies and courses along with experience in wind fluid dynamics, solid mechanics, and computational engineering.

Soft skill: An ideal PhD candidate will demonstrate team working skills and problem-solving aptitude.

Strong written and verbal communication skills in English are required.

Initial confidence with High Performance Computing hardware and software facilities will be appreciated, but not strictly required.

For further information and expression of interest, write to: luca.bruno@polito.it.