



PhD in INGEGNERIA STRUTTURALE, SISMICA, GEOTECNICA / STRUCTURAL SEISMIC AND GEOTECHNICAL ENGINEERING - 39th cycle

**PNRR 118 PNRR Research Field: FATIGUE BEHAVIOUR OF FRC AND DESIGN OF
FATIGUE SENSITIVE FRC STRUCTURES**

Monthly net income of PhDscholarship (max 36 months)
€ 1275.0
In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	<p>Fatigue phenomena caused deterioration and collapse of numerous concrete structures [1]. Fiber reinforced concretes (FRC) proved to be a promising solution to address fatigue design [2]. Owing to their bridging effect, fibers provide ductility and control the post-peak behavior of the material. The development of high-performance concretes (HPC) paved the way for broader applications of FRC. One of the most promising fields for the application of HPSFRC materials are infrastructures – bridges, pavements, infrastructures for energy harvesting –, which are often exposed to cyclic loading during their service life [3,4]. Therefore, the characterization of the fatigue behavior of the material is a crucial aspect for structural design [5].</p>
Methods and techniques that will be developed and used to carry out the research	<p>Currently available codes tackle the issue of fatigue failure prediction with the Palmgren-Miner rule, a simplified approach based on the performance degradation as a function of the stress levels and the number of cycles. The research will start from this approach was adopted to critically analyze the sensitivity of the prediction to the data populating the interpolated Palmgren-Miner curve, which will be "harvested" by means of dedicated experimental campaigns on a portfolio of fibre reinforced cementitious composites devised for different applications and on a range of stress scenarios including compression,</p>



	<p>flexure and shear. This will allow also the verification of failure domains based on the S-N models provided by the fib-ModelCode 2010 [6].</p> <p>Another approach which will be followed moves from the proposal by Stephen and Gettu [7]. Crack pattern will be identified through digital image correlation techniques, addressing the evolution of the crack in the central section from the strain localization to the progressive failure. This will be also correlated to other sensor measurements and embedded into suitable criteria which will allow not only to quantify the fatigue service life of materials and structures but also to set up warning criteria to detect the onset of unstable conditions on a structure, which could be used, e.g. in digital twin and monitoring systems, to prevent abrupt and unexpected failures.</p> <p>[1] Comité Euro-International du Béton, Fatigue of Concrete Structures: State of the art report, 1989. [2] D.E. Otter, A.E. Naaman, Properties of Steel Fiber Reinforced Concrete under Cyclic Loading, ACI Mater J. (1988) 254-261. [3] F.Z. Kachkouch, C.C. Noberto, L.F. de Albuquerque Lima Babadopulos, A.R.S. Melo, A.M.L. Machado, N. Sebaibi, F. Boukhelf, Y. el Mendili, Fatigue behavior of concrete: A literature review on the main relevant parameters, Constr Build Mater. 338 (2022). [4] C.S. Wang, M.S. Zhai, L. Duan, Q. Wang, Fatigue service life evaluation of existing steel and concrete bridges, Advanced Steel Construction 11 (2015) 305-321. [5] M.K. Lee, B.I.G. Barr, An overview of the fatigue behaviour of plain and fibre reinforced concrete, Cem Concr Compos. 26 (2004) 299-305 [6] Fédération internationale du béton (fib), fib Model Code for Concrete Structures 2010, 2010. [7] S.J. Stephen, R. Gettu, Fatigue fracture of fibre reinforced concrete in flexure, Materials and Structures/Materiaux et Constructions 53 (2020).</p>
<p>Educational objectives</p>	<p>The candidate will be trained in advanced topics related to the structural design and applications of advanced cement based materials, including durability testing, life-cycle analysis and advanced manufacturing techniques.</p>



Job opportunities	The topics of the proposed PhD scholarship are crucial in the development of the construction sector. The candidate, once graduated, can spend his skills into a broad portfolio of engineering firms and construction companies and the healthy relationships of the research group with industry will surely open broad possibilities.
Composition of the research group	0 Full Professors 2 Associated Professors 2 Assistant Professors 10 PhD Students
Name of the research directors	Liberato Ferrara

Contacts	
liberato.ferrara@polimi.it phone +390223994387	

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	637.5 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	--
By number of months at the company	0
Institution or company where the candidate will spend the period abroad (name and brief description)	Possible hosts: Cemex Research Group AG; Karlsruhe Institute of Technology; Technical University of Delft; TU Darmstadt
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information	
Educational activities The Ph.D. course supports the educational activities of its Ph.D. students with an additional funding equal to 10% of the scholarship, starting from the first year.	
Teaching assistantship Ph.D. students are encouraged to apply, upon prior authorization, to the calls to support teaching	



activities at the undergraduate and Master levels at Politecnico, being paid for that. The teaching assistantship will be limited up to about 80 hours, maximum half of them devoted to teaching and classroom activities and the rest to support classworks and exams.

Computer availability

Each Ph.D. student has his/her own computer for individual use.

Desk availability

Each Ph.D. student has his/her own desk, cabinet and locker.