



**POLITECNICO  
DI TORINO**

Dipartimento  
di Ingegneria Strutturale,  
Edile e Geotecnica

## PhD in Civil and Environmental Engineering

### Research Title: “The Circular Economy in the construction sector: enhanced cementitious materials with low CO<sub>2</sub> impact”

Funded by	Politecnico di Torino - DISEG
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Context of the research activity	<p>The manufacturing of concrete requires a high consumption of energy and the production of high quantities of CO<sub>2</sub> and atmospheric pollutants. For this reason, experimentation of innovative and sustainable materials is playing a very important role in concrete technology.</p> <p>Therefore, “Reusing” is the key word to win the challenge of green technology construction. In this sense, the char - solid by-product of biomass energy recovery - becomes an emblematic material with a thousand facets, as its properties make it possible to use it both as a filler, to modify the nanogranular nature of the cement matrix, and as a substitute for clinker, thus reducing the carbon footprint and the emissions of greenhouse gases linked to the production processes of cement.</p> <p>In the white paper “The role of cement in the 2050 low carbon economy”, published by the European Cement Association (CEMBUREAU), several points to reduce emissions of CO<sub>2</sub> are indicated, and this research project is focused on point 1 (Resource</p>
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	<p>efficiency). The impact of char on the low carbon cement-based economy is expected to be strong, since char is a by-product of energy recovery processes that will become always more diffuse, and since it provides a substantial improvement of chemical, physical, and mechanical properties of cement.</p> <p>The development of convincing technologies for turning char into value within a construction material technology entails formidable challenges and opportunities, that can be taken with a polyhedral approach. For this reason, the research group is multifaceted with skills related to different disciplinary sectors and the strength of the project lies in the multidisciplinary approach, thus promoting the implementation of circular economy strategies in accordance with the EU action plan.</p>
<b>Objectives</b>	<p>The innovation of this PhD Research project will be to provide a full investigation of the chemical, physical and mechanical effect of various biochars within the cement matrix, to produce high performance cement-based materials with a great effectiveness in terms of flexural and compressive strength, toughness and ductility, low carbon emissions. The literature is already giving clear signals about the excellent properties of char-containing cement, but a clear explanation of the effect of this material on cement properties must still be provided, in order to be able to design a new generation of cement-based materials with enhanced properties and lower carbon footprint. Thus, the aim is to produce a sustainable biochar-based building material and to provide a full characterization and explanation of its behaviour. Specifically, some topics will be deeply analysed:</p> <ul style="list-style-type: none"><li>• Proper Dispersion: analysis of the size and specific surface of biochar particles and their influence on the workability of the mixture; dispersion processes and development of techniques to evaluate the effective dispersion.</li><li>• Optimal Mix-Design: study of the water-to-cement ratio, of the optimal quantity of biochar particles with respect to the weight of the cement, and of the interaction of biochar with additives.</li><li>• Mechanical Properties: study of flexural strength (through 3-point bending tests in Crack Mouth Opening Displacement mode), compressive strength, fracture energy (by evaluating the area under the P-CMOD curves), all in compliance with existing standards and at different curing-times (7 and 28 days).</li><li>• Toughness Mechanisms: analysis of fracture surfaces to understand the bond between biochar and matrix, to evaluate Micro/Nano mechanisms of toughness.</li></ul>



	<ul style="list-style-type: none"><li>• Physical and thermal properties: a variety of physical properties will be studied to understand the effect of biochar insertion in the cement: density, porosity type and distribution, thermal expansion, thermal conductivity, behaviour at high temperature.</li><li>• Durability: study of water sorptivity, volume of permeable voids, chloride permeability and diffusion of biochar-based cement (after curing at 28 and 90 days).</li><li>• LCA: Life Cycle Assessment</li></ul>
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<b>Skills and competencies for the development of the activity</b>	The candidate should be proficient both in the mechanical characterization of cement-based materials and in the nano- and micro-particles technology.
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