

French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of engineering schools/universities. The document also provides information about the supervisor.

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PhD information	
Title	Passive Bio-Geo-Based Cooling of Urban Heat Islands: A Coupled Thermal, Hydric, and Mechanical Approach in a France–China Context by 2100
Main topics regards to CSC list (3 topics at maximum)	IV-7. Materials for environment and ecology IV-12. Environmental behavior and failure of materials VI-4. Intelligent construction

Required skills in science and engineering	Perform experimental tests, perform analytical and numerical analysis, in-depth knowledge of mechanics of materials, analysing and interpreting data, communication, self-management.
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Subject description (two pages maximum including biblio)

Context and objectives

This project is framed by the French national climate adaptation pathway (TRACC), which anticipates an average warming of about +2 °C by 2030, +2.7 °C by 2050, and +4 °C by 2100. Under these conditions, urban heat islands become a lasting issue for comfort, health, and continuity of use, especially during heat waves and hot nights, so adaptation cannot rely solely on active air-conditioning, which would increase electricity demand and anthropogenic heat release in cities. The project investigates bio- and geo-based materials and systems for pavements, façades, roofs, and envelopes, acting through complementary mechanisms: solar reflectance, reduced heat storage, coupled heat-and-moisture transfer, water retention or redistribution, and interaction with water vapour. The aim is not only to quantify the initial cooling effect of reflective or permeable pavements, earth-based plasters, dense bio-based layers, and water-efficient green systems, but also to track how this performance evolves under clogging, soiling, ageing, and maintenance constraints. The methodology combines experimental characterization, thermal and hydric monitoring, microstructural analysis, and hygrothermal modelling, building on prior results on earth-based materials and on the hygrothermal assessment of raw-earth envelopes under contrasted climates. Beyond assessing existing options, the project aims to propose a robust comparison and selection framework for a +4 °C France, by linking materials, green systems, resource constraints, and practical implementation, so as to identify passive cooling strategies that remain technically relevant, materially sober, and environmentally consistent over time.

A cooling material is only as useful as its ability to keep performing while carrying real loads, so the project will add a dedicated mechanical study alongside the thermal and hydric one. For earth-based and fibre-reinforced envelope materials (earthen plasters, raw-earth or rammed-earth layers, hemp- or flax-reinforced composites), this means quantifying compressive and flexural strength, drying-shrinkage strain, and crack initiation as a function of fibre type and content, since natural fibres are known to bridge micro-cracks, reduce shrinkage, and improve post-cracking toughness in earthen matrices, though at the cost of a generally low and brittle tensile strength that must be characterized rather than assumed. Recent work on rammed-earth mixes optimized with cement, aggregate, and natural fibre content shows that a well-chosen formulation can markedly increase compressive strength while cutting shrinkage, which is directly relevant to seismic and freeze–thaw exposure as well as to the long-term dimensional stability sought here.

For pavement-type solutions, the mechanical dimension concerns the coupling between thermal cycling and surface durability: reflective coatings and permeable surfacings are subject to rutting, cracking, and loss of skid resistance under repeated traffic and thermal loading, and their solar reflectance and cooling performance have been shown to degrade with wear and ageing. The thesis will therefore combine

mechanical testing (uniaxial and splitting-tensile tests, cyclic or accelerated-ageing loading, digital image correlation for strain-field mapping) with the thermal and hydric instrumentation already planned, so that the microstructure–performance–durability chain extends from cooling efficiency to load-bearing capacity and crack resistance. This provides a common, multi-criteria basis — thermal benefit, water demand, mechanical integrity, maintenance need — for comparing candidate solutions rather than assessing cooling in isolation.

China gives this project both a strong rationale and a natural comparative ground. Rapid urbanization has made Chinese cities a focal point of urban-heat-island research, and China's own National Climate Change Adaptation Strategy 2035 sets long-term principles for monitoring and resilience across regions with contrasting exposure, while national reviews document how UHI affects building energy demand and how mitigation levers such as cool roofs carry a climatic trade-off between hot southern and cold northern cities. This diversity, spanning severe-cold, hot-summer/cold-winter, and hot-summer/warm-winter zones, offers a broad natural laboratory for testing which cool-surface and bio-geo-based strategies stay viable across contrasted and evolving climates — echoing the multi-criteria logic sought for a +4 °C France.

The mechanical dimension adds a further point of convergence: earthen construction remains widespread in rural northwestern and southwestern China, and recent Chinese studies have both measured the hygrothermal behaviour of traditional rammed-earth walls and optimized fibre- and cement-modified rammed-earth mixes to improve compressive strength and reduce shrinkage for seismic-prone regions. These mechanical datasets, obtained on material bases close to the fibres and earthen matrices considered here, offer a valuable point of comparison for the coupled thermal-mechanical-durability framework targeted in this thesis, and open a path toward a shared France–China reading of how bio-geo-based cooling solutions age and perform under both mechanical loading and increasingly extreme climates.

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