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.

Supervisor information	
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PhD information	
Title	**Raw earth construction and its resilience for present and future heat waves.**
Main topics regards to CSC list (3 topics at maximum)	VI-3. Ingénierie du développement durable et fabrication à coût réduit Sustainable development engineering and lower cost manufacturing

	VI-4. Construction intelligente Intelligent construction V-7. Matériaux pour l'environnement et l'écologie Materials for environment and ecology
Required skills in science and engineering	Building energy performance, simulation

Subject description (two pages maximum including biblio)

In recent years, the use of earth-based materials in sustainable construction has become increasingly popular. Raw earth is an abundant and recyclable resource that has been used as a building material for centuries. Despite its many benefits, such as its affordability and low environmental impact, it has suffered from a lack of recognition and standardization. However, earthen construction has become a promising building technology that offers multiple advantages (Shubbar et al. 2019).

Earthen construction is 'environmentally friendly'. The production of traditional building materials, such as cement and bricks, requires a large amount of energy and generates significant amounts of greenhouse gases. In contrast, earthen materials are readily available and require minimal processing. This makes them a low-carbon alternative to traditional building materials.

Earthen materials also have excellent thermal inertia. Thermal inertia refers to a material's ability to absorb and store heat. This property helps regulate indoor temperature and enhances the thermal resilience of buildings during hot periods (Truchet et al 2024). Earthen materials have a high thermal mass, meaning they can store large amounts of heat, which can then be released slowly over time.

Earthen materials also have remarkable hygroscopic properties, which make them ideal for indoor construction (Cascione et al. 2019). Hygroscopic materials can absorb and release moisture depending on the relative humidity of the surrounding air (Losini, 2023). This property is essential for maintaining human comfort and health in indoor environments. However, the impact of moisture buffering on summer comfort and the resilience of earthen constructions against heat waves is still an open research question (Legros et al. 2020) that will be investigated in the present doctoral work.

This will be done by modeling performance at the building level. The assessment of a realistic contribution remains a scientific challenge. The whole building performance is a complex equilibrium of heat and mass transfers through the building envelope, submitted to exterior boundary conditions (weather), as well as indoor systems, occupants' behavior and needs, etc. (Soudani et al 2016, 2017) Numerical simulations will be used to test a wide range of configurations, involving varying building geometry, occupancy scenarios, HVAC systems and weather conditions, including future climates (Toesca et al 2023).

The physical representativity of the model at the building scale will be verified using experimental results from literature. The direct use of existing models (such as EnergyPlus) with adapted material properties is anticipated, or special developments such as co-simulation between a whole building software and an on purpose made model, is foreseen.

To precisely and robustly assess the impact of raw earth construction on low CO2 footprint building performance, not only a large parametric study will be conducted, but statistical methods will also be used. More specifically, sensitivity studies and computations of Sobol indices will allow to assess the relative influence of raw earth as compared to other building components (Goffart et Woloszyn, 2021). Using and understanding such ANOVA methods of non-linear hygro-thermal phenomena, with partly dependent material parameters is still a challenge, and adaptation of existing methods may be needed. By conducting these tests for different weather files representatives of actual and future climates, it is possible to evaluate the thermal resilience of the building against heat waves.

As a complement, life cycle assessment will be conducted to assess the environmental impact of the house over its entire lifecycle, including the production, use, and disposal of raw earth construction, focusing on the contribution of raw earth to the use phase during summer.

Cascione, V., Maskell, D., Shea, A., & Walker, P. (2019). Full-scale simulation of indoor humidity and moisture buffering properties of clay. *Earthen Dwellings and Structures: Current Status in their Adoption*, 395-406.

Goffart, J., & Woloszyn, M. (2021). EASI RBD-FAST: An efficient method of global sensitivity analysis for present and future challenges in building performance simulation. *Journal of Building Engineering*, *43*, 103129.

Legros, C., Piot, A., Woloszyn, M., & Pailha, M. (2020). Effect of moisture buffering on surface temperature variation: Study of different indoor cladding materials. In *E3S Web of Conferences* (Vol. 172, p. 06002). EDP Sciences.

Losini, A. E., Grillet, A. C., Vo, L., Dotelli, G., & Woloszyn, M. (2023). Biopolymers impact on hygrothermal properties of rammed earth: from material to building scale. *Building and Environment*, *233*, 110087.

Soudani, L., Fabbri, A., Morel, J. C., Woloszyn, M., Chabriac, P. A., Wong, H., & Grillet, A. C. (2016). Assessment of the validity of some common assumptions in hygrothermal modeling of earth based materials. *Energy and Buildings*, *116*, 498-511.

Soudani, L., Woloszyn, M., Fabbri, A., Morel, J. C., & Grillet, A. C. (2017). Energy evaluation of rammed earth walls using long term in-situ measurements. *Solar energy*, *141*, 70-80.

Shubbar, A. A., Sadique, M., Kot, P., & Atherton, W. (2019). Future of clay-based construction materials–A review. *Construction and Building Materials*, *210*, 172-187.

Toesca, A., David, D., Johannes, K., & Lussault, M. (2023). Generation of weather data for the assessment of building performances under future heatwave conditions. *Building and Environment*, *242*, 110491.

Truchet, S., Jay, A., Wurtz, E., Anger, J., Brun, A., & Bernaud, P. (2024). Impact of thermal inertia coupled to natural night ventilation. A case study for a high performance building in continental climate. *International Journal of Ventilation*, *23*(1), 25-38.