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

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information	
Family name	LEKLOU
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Lab name	Research Institute in Civil and Mechanical Engineering (GeM – UMR CNRS 6183)
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Polytech name	POLYTECH NANTES
University name	UNIVERSITE DE NANTES
Country	France

PhD information	
Title	3D printing of building materials - application to the construction of the structural walls of buildings
Main topics regards to CSC list (3 topics at maximum)	Civil engineering; Mechanics; Materials

Required skills in science and engineering	• Knowledge in civil engineering materials and their durability & transport phenomena and rheology • Competence in physics and fluid mechanics • Programming (Matlab)

Subject description (two pages maximum)

PROBLEMATIC:

Building design with 3D printing technology is experiencing considerable growth worldwide because of the time savings on achieving the elevations it could eventually provide and the freedom of form for architects, the reduction waste, the functionalization of the surfaces it allows, the reduction of hardship at work, the increase in skills of site staff, the improvement of execution tolerances, the reduction of defects ... The development of these techniques goes hand in hand with the migration of the construction industry towards taking into account the principles of sustainable construction. First developed by Khoshnevis in the 1990s, 3D printing for construction had a period of latency before starting tentatively in the second half of the 2000s, but since 2010, the number of projects and publications on the subject knows an exponential growth.
On a local level, Water / Geomaterials Interactions team (IEG) of GeM – UMR CNRS 6183 laboratory has developed a large-scale additive manufacturing technique for building applications in collaboration with the Nantes Digital Science Laboratory (LS2N-UMR CNRS 6004). This technique, called Batiprint3D, consists of constructing a polyurethane foam formwork by depositing two parallel cords of PU foam between which self-compacting concrete is poured. This technique was developed between 2016 and 2017 and was implemented on the scale 1 demonstrator: Yhnova. The walls of this 95 m² house, located in Nantes and whose owner is Nantes Métropole Habitat, were built in 54 hours. In addition to the technical developments required to deploy the on-site process, the Yhnova construction also required a prior step of technical justification of the process with respect to the numerous construction standards. These justifications presented to CSTB made it possible to obtain a technical evaluation of experimentation for the Yhnova project, a prerequisite essential for the start of the construction site and the insurability of the building. This approach makes Yhnova the first building built by 3D printing and respecting the construction standards of a developed country. The transition from the laboratory to the construction site made it possible to better understand the possible improvements of the Batiprint3D technique in terms of materials, future technical developments on the process or construction phasing. Now, new developments are being studied both in the GeM and LS2N, notably to put a work of techniques of direct deposition of the structural material (concrete or mud) and to better evaluate the durability of the structures produced by this new constructive process.

OBJECTIVES OF THESIS:

The thesis focuses on the development of cementitious matrix or raw earth materials suitable for 3D printing. The specifications, set by Buswell for the development of materials suitable for large-scale 3D printing, indicate that they must be pumpable, printable and buildable, and have a time implementations compatible with the process (open time). It will therefore be necessary to study the parameters that influence the rheological properties of the fresh materials and the properties of use of the hardened material. Particular attention will be paid to studying the kinetics of hardening of materials in a controlled environment and in a real environment for different formulations of cementitious pastes and mud. Particular attention will be paid to limiting the consumption of materials with high added value or high environmental impact in the process. The effect of the incorporation of synthetic fibers, mineral or vegetable, will also be studied in order to determine their influence on the behavior on the one hand, but also on the properties of use of the materials and in particular the mechanical properties in static solicitation and dynamic.

The work will break down into several stages:
(O1) Process: Measurement of material properties (rheological properties and cure rate) for different standard formulations from the literature or developed in the laboratory. Realization of small specimens and large structural elements with variation of the deposition parameters (deposition effector displacement velocity, layer height and thickness, deposition height). Verification of stability models of printed walls from the literature.

(O2) Mechanics: Mechanical study of cohesion between strata and macroscopic mechanical properties of structural elements. Development of a model for predicting mechanical properties taking into account material properties and process parameters.