PHD RESEARCH PROJECT PROPOSAL
Centre for Doctoral Training in Energy Resilience and the Built Environment

This template has been created to capture the essential elements of PhD research project proposals. The project proposed will be offered to students in the ERBE Centre for doctoral research. If you have more than one project to propose, use a separate template for each one.

The template is intended as an aid to those proposing projects to ensure a complete description. Please ensure you complete all sections in a way that draws students’ attention to the value of the project to them and to others.

All ERBE CDT PhD projects need to address a matter related to at least one of the ERBE three themes:

- Flexibility and Resilience
- Technology and System Performance
- Comfort, Health and Wellbeing

Please complete all sections in Arial 11pt. Allow text boxes to expand as needed.

PROJECT TITLE: Evaluating the performance of 3D Concrete Printing for buildings

POSSIBLE SUPERVISORS (usually the project proposer and A N Other): R. Buswell, D. Allinson

CONTEXT (what is the wider social, political and technical context that leads to this work., why is it important):

3-D concrete printing is a recognised modern method of construction which is being applied to the production of dwellings. There is planning permission which has been gained for the first social housing to be constructed in the UK using the technology. However while planning consent is based on approximations to a continuous brick structure in terms of a structural capacity, little is known about the thermal and hygrothermal performance of these buildings, which is of critical importance if the technology is going to be widely adopted in the UK.

PROJECT DESCRIPTION:

The project would involve the design and production of a 3-D concrete printed wall structure, which will be based on UK and European code compliant structures that are in existence, or have planning permission granted. Manufacture would be at the 3DCP printing facilities at Loughborough University. Performance and durability of the concrete material will be carried out, and critically a full-scale panel would be manufactured for testing in the Hygrothermal Test Facility. The thermal and hygrothermal (moisture) performance of the construction would then be evaluated.

During the project supervisors would also seek the potential to collaborate with providers of 3DCP in order to gain some in situ measurements to support the laboratory work. In the UK project was still in the final stages of planning, and so hopefully given a successful project and candidate in October 2023, we would be in a good position to negotiate data collection in a completed structure(s).
**AIMS and OBJECTIVES:**

To evaluate the hygro-thermal performance of 3DCP structures in order to demonstrate them as a viable method of construction for the production of dwellings both in the UK and internationally.

1. Establish the state of the heart in terms of the global production of 3-D concrete printed buildings together with wall construction and insulation design approaches in order to determine compliant approaches for the UK (and EU) market.
2. Undertake a critical review to establish the key performance characteristics required of structures, and relate these to modern methods of construction and 3-D concrete printing in particular.
3. Work with architect partners to design concrete printed structure using appropriate technology and manufacturing parameters, which would include the material design thickness size of layers layering strategies, insulation strategies etc.
4. Measure the properties of the 3DCP materials in small scale lab tests.
5. Manufacture a full-scale panel with support from the 3DCP printing group.
6. Design and undertake a set of performance tests in the Hygrothermal Test Facility and compare the performance of the full-scale panel with existing traditional methods and modern methods of construction and establish any key differences limitations and benefits of 3DCP technology.
7. Critically review the results in order to determine key research and development aims to improve the performance of the structures, and to highlight the potential benefits.
8. Generate design models and approaches that would be appropriate to support the wider adoption of the technology through embedding know-how within UK design practice.

**METHODS: (Measurements, data sources, methods of analysis, etc)**

- 3DCP facilities at Loughborough for production
- Durability assessment at Loughborough Land and the UKCIRC centre
- Hygrothermal Test Facility and guarded hot box at Loughborough

**EXPECTED OUTCOMES:**

New testing procedures for 3DCP structures; new data on performance; design guidance and recommendations to support wider adoption of the technology; feedback into industrial production platform providers on UK market requirements for the technology.

**MULTIDISCIPLINARY ASPECTS (what different skills and knowledge will this project develop)**

Building physics, materials science, structures and design

**BUDGET, STAKE HOLDER AND OTHER SUPPORT (Any financial or in-kind industry support offered, costs of T&S and materials if substantial):**

Anticipated: In kind design support from Cundall (structural engineering aspects) and Foster and Partners (architecture and compliances aspects) and Harcourt Technologies Ltd. For assess to the First UK 3DCP buildings for field testing.

**SKILLS and INTEREST REQUIRED OF STUDENT.**

This is an ambitious project, which will need significant dedication and drive from the student. They will have to be very good communicators and be able to hold conversations with leading design practices and industry and also able to collaborate internationally. They will need to be very technical and mechanically minded in order to drive the testing equipment we have, they also need to have interest in aspirations to learn how to drive through the concrete printing processes and equipment ideally with some coding 3-D modelling design.
experience. They will also need to develop an understanding and appreciation of the thermal and hygrothermal performance of materials and in particular cement based motors in concrete which will form the structural element of the building. A sound understanding of engineering physics will be a significant benefit.

**POSSIBLE ROLE OF INTERN and INTERNATIONAL PLACEMENT** (The ERBE Centre sees value in PhD students supervising and intern to assist them in their work where possible. Likewise time spent in an overseas research institution can enhance students’ perspective.):

3D concrete printing group is well-connected internationally and is also well known to COBOD, who’s machines are building the first building in the UK with Harcourt Technologies. Addition there are strong links to the wind haven where the milestone project has been completed in the Netherlands, we would actively explore the potential National collaboration with organisations that have been involved with code compliant construction projects within Europe. There are various research groups around the world with experience of measure hygrothermal performance.