Sample SWEP Proposal

REimagining Design to Enable Safe & Sustainable Innovative Global iNfrastructure (REDESIGN) Researcher

Brief Overview and History of the Project

The construction of reinforced concrete (RC) infrastructure is responsible for approximately 10% of anthropogenic CO2 emissions globally each year. To meet the Intergovernmental Panel on Climate Change's (IPCC's) emission reduction targets by 2050, a step change is required in the construction industry. New approaches to reducing the CO2 emissions from RC structures will need to use optimized structural forms to maximize structural efficiency and low carbon binders, and progress is being made in both areas. However, when evaluating the resilience of RC structures, architects and engineers have traditionally relied on prescriptive code-based approaches based on experience and supported by material and structural element testing. This approach has proven adequate when used in conjunction with traditional approaches to RC construction such as the use of largely rectilinear forms. The potential negative impact of using new construction materials and optimized approaches is that there can be disastrous consequences if not implemented appropriately. Such adverse consequences may take decades to manifest, but may then create a crisis in the sector; as illustrated by the Grenfell Tower fire and the resulting "UK cladding crisis". Because of this, the industry is rightly reluctant to change, and relies on proven, conservative (yet wasteful) approaches but this reluctance stands in sharp contrast with the urgent need to change.

The key challenge is to provide the construction industry with the tools and assurances required to design and implement resilient low-carbon concrete structures by overcoming barriers to innovation. Research about the performance of optimized elements and structural systems is needed to provide quantitative evidence for design. Additionally, removing concrete from an element within a structure means that the resilience of the structure as a whole system will be impacted, and yet structural optimization methods and tools do not yet exist to accurately evaluate the impacts this may have on structural safety and robustness. One of the key limiting factors when evaluating the performance of structural elements and systems is the lack of sensing tools to provide the required quantitative data. Distributed fibre optic sensors (DFOS) can potentially provide robust quantitative data sets and have been used to evaluate the performance of RC structures in the lab and the field. Research is needed to understand the sociotechnical barriers to innovation in the industry, and to develop new methods of collaborative design that breakdown these barriers. To overcome these limiting factors, a high-risk, multidisciplinary approach is required.

The current SWEP project is part of a large multi-year project with partners from academia, industry and government, including the Universities of Edinburgh and Toronto, to develop innovative solutions to this critical challenge. As a result, the successful candidate will have the opportunity to work with experienced researchers and practising engineers in this field. This SWEP project is designed to give the successful candidate the opportunity to experience what is involved in being a civil engineering researcher by joining a multi-disciplinary research team developing and evaluating new approaches to the design of RC infrastructure to ensure resilience. The candidate will work on an experimental campaign involving the use of sensors and/or numerical analysis to better understand the resilience of RC infrastructure. There will be four main tasks within the project: (i) assisting with experiment design (either physical or numerical), (ii) conducting a series of experiments including the use of advanced instrumentation / numerical modeling, (iii) analysis of the experimental results and experimental modification, and (iv) results dissemination to the research team. The novel technologies include several distributed fibre optic sensor systems, which are the only ones in use for civil engineering applications in Canada, and advanced finite element analysis software. The successful candidate will work under Dr. Hoult's direct supervision but will also interact with other graduate students in Dr. Hoult's research group so that they can maximize their exposure to a variety of research projects.

In order to facilitate more environmentally aware yet resilient structural designs, engineers require better information about the performance of structures. Thus, projects such as this, that increase our understanding of structural behaviour, play an important role at all three levels of government. The City of Kingston is a key partner in this research and will benefit directly as this research will lead to better specifications for future City construction projects. The Ministry of Transportation Ontario would also benefit from the resilient low carbon concrete structures being developed and as a result of this research they would be able to improve the design of new structures by reducing the embodied CO2 while still maintaining system resilience. Federal government departments such as Transport Canada are responsible for investigating and providing guidance on the future of transportation infrastructure. Thus, they are keen to work with researchers to understand new approaches to structural design. In addition, it is the Federal Government that is taking the lead on developing carbon reduction mandates for infrastructure. The research also fits within Queen's Strategic Research Plan, namely in the areas of: (i) Sustainability, Environment and Resources and (ii) Interdisciplinary research in materials, computational analytics and human-machine interactions. A key aspect of the research involves refining approaches to structural design so they use less material will have a significant benefit since as noted 10% of CO2 emissions come from cement production and the proposed research aims to cut that figure in half addressing challenges associated with areas. To put this figure in context, the entire airline industry produces 2% of annual emissions, and thus this 50% reduction would represent the equivalent of eliminating the emissions of the airline industry twice over. Additionally, even a small reduction in the amount of material used would represent significant savings in an industry that is worth $73.8 billion. These savings on infrastructure could then be used by governments to fund other environmental initiatives such as green energy. This research will also further the state-of-the-art in terms of the use advanced sensor technologies (e.g. fibre optic sensors and digital image correlation). These technologies will not only assist in the design of new structures but could also be used for the assessment of in-service civil infrastructure assets.

Description of Role

A research assistant (RA) is required for a 16 week project to participate in the REimagining Design to Enable Safe & Sustainable Innovative Global iNfrastructure (REDESIGN) research program. The goal is to better understand the performance of low carbon structural elements as part of a system in order to assess their resilience and improve the available design techniques. Working under Dr. Hoult's supervision, the candidate will work as part of a research team. The project will involve designing, constructing, and running a series of experiments (either physical or numerical) intended to investigate how removing carbon from concrete using both shape and material optimization effects the short- and long-term performance of these elements and the building as a whole. The successful candidate will help to conduct a series of experiments aimed at advancing the state of the art in this area. The RA will then work with the research team, led by Dr. Hoult, to analyse and model the results. Finally, the RA will disseminate these results to the research team.

The successful candidate will work mainly in the Ellis Hall Structures Lab. The Ellis Hall Structures Lab enables structural specimens, from scale models to full size structural elements, to be tested to destruction under controlled conditions. They will work with members of the research team to develop improved structural design techniques as well as to understand the performance of novel structures through the use of advanced sensor technologies.

The overall progress of the candidate will be supervised by Dr. Hoult. The candidate will also be supervised by graduate students who are experts in their individual field in order to give the graduate students invaluable training experience.

Required Qualifications

It is anticipated that the successful candidate will have finished their second or third year in Civil Engineering (although highly qualified candidates from a related discipline will also be considered). The successful candidate will be self-motivated and able to work independently.

This project offers a unique opportunity for a student to apply the skills they have gained as part of their core undergraduate studies to a research project. Courses that will be useful include: CIVL 231 - Solid Mechanics II and CIVL 330 - Structural Analysis, CIVL 331 - Structural Design I, CIVL 340 - Geotechnical Engineering I and CIVL 341 - Geotechnical Engineering II. Skills developed as part of this project will benefit students who are hoping to work for companies that conduct research and development, students hoping to pursue a career in academia, and students who wish to work for structural or geotechnical engineering consultancies.

Learning Plan

Skills Development

At the end of this project it is anticipated that the following skills will have been developed:

- Experimental planning
- Experimental construction and testing
- Health and Safety
- Professional skills
- Project management

Development Opportunities

Experimental planning skills - the candidate will be given the opportunity to design experiments and then follow the process through to implementation. These skills will be developed through a combination of weekly meetings with Dr Hoult, ongoing instruction from a graduate student, and interactions with the Department's technical staff. Dr Hoult will meet with the RA on a weekly basis to review the previous week's activities as well as to discuss the week ahead including the ongoing experimental campaign. The RA will work directly with graduate students who will guide and instruct the RA on a day-to-day basis. Interactions with technical staff will also be required if the work is lab-based to arrange for the ordering of supplies and the fabrication of experimental equipment, which will give the RA an opportunity to communicate technical concepts to a variety of individuals.

Experiment construction and testing skills - the candidate will be involved in the instrumentation, construction, and running of experiments, or the development of numerical models. Skills will be gained through hands on work or numerical modelling conducted under the supervision of experienced researchers and technical staff. The RA may spend a minimum of 50% of their time in the Department's laboratory facilities (in Ellis Hall). In the lab, the student will work directly with a graduate student who will teach them how to fabricate specimens. The RA will also work with the graduate student and technician to setup and test several specimens.

Health and Safety - one of the most important aspects of work in civil engineering is that the work is conducted safely. The candidate will be given both formal training and informal guidance about how to work safely in a civil engineering environment. Before starting work in the lab, they will take the Department's online safety training course, CIVL 801. They will also meet with Dr Hoult to discuss the specific safety training required for their project. This training will give them an appreciation of the importance of safety and what it means to create a safety culture that they can carry with them throughout their career.

Professional skills - the candidate will work with colleagues in the Civil Engineering Department including faculty members, graduate students, and technicians to develop skills such as time management and preparation. The weekly meetings with Dr Hoult as well as other meetings throughout the project will enable the candidate to develop these skills. For example, many of these meetings will require the candidate to prepare in advance as well as to take notes during the meeting and execute a series of tasks within a specified time frame.

Project management - the candidate will be given the opportunity to undertake a set of experiments as part of the larger research project. The candidate, with the help of Dr. Hoult, will learn how to budget both time and money to ensure a successful outcome. At the beginning of the project, Dr Hoult will lay out clear steps and deadlines that need to be accomplished during the week. As the project progresses the candidate will be given more ownership of the project to the point where, towards the end of the project, the candidate will use the weekly meetings to update Dr Hoult on their progress.

Communication - both oral and written communication skills will be developed over the course of the summer. The candidate will not only interact with Dr Hoult but also other members of Dr Hoult's research team, other graduate students, and the technical staff. The candidate will be asked to attend the weekly structures group meeting where they will present their research and research needs to the other researchers in the structures group. In addition, the deliverables for this project will include a comprehensive data set to be used for ongoing analysis, a final handover document of the type that would be requested by a client as well as the potential for conference and/or journal publications should the research prove successful.

Unique Opportunities

As a result of several recent investments from the Canada Foundation for Innovation (CFI), the Natural Sciences and Engineering Research Council, and Transport Canada, the Civil Engineering Department has lab facilities and equipment that are unique amongst civil engineering departments in Canada, and in many cases the world.

The fibre optic strain measurement systems used by Dr Hoult's research group are exciting new tools for understanding structural behaviour that will provide the candidate with a skill set not available to students outside of Queen's. In addition, there is the potential opportunity to be involved with world leading researchers at the Universities of Edinburgh and Toronto. The successful candidate will be given exposure to experimental data acquired using these sensors. Dr Hoult's collaborations with industry and government also mean that the successful candidate will be given the opportunity to interact with engineers and technical staff from a variety of backgrounds who have a wealth of experience. This will not only allow the successful candidate to gain exposure to a number of potential career paths but also develop a network of contacts. In addition, the Department is among the top, if not the top, civil engineering research group in Canada and so the candidate will have the opportunity to interact with a number of researchers undertaking cutting edge research.