



**Elsa Defforey** is currently completing a Master's degree at Université Laval, as part of a double degree program with Arts et Métiers, France, School of General Engineering. Her research project aims to adapt accelerator conditions to spray concrete of low-carbon binders, particularly Type 1L (GUL) cement. She chose to specialize in civil engineering after

gaining valuable hands-on experience during an internship on a construction project, and she is now committed to integrating an approach that is both ecologically thoughtful and practically feasible into her graduate research project.

## DEFFOREY'S RESEARCH PROJECT THE LABSPRAYER: A TOOL TO EXPLORE WET-MIX SPRAYING OF LOW-CARBON BINDERS

Reducing the carbon footprint of cementitious materials is a major ongoing challenge in the entire construction industry, and the shotcrete world is no exception. As clinker production is responsible for the largest share of concrete's carbon emissions, the use of low-carbon binder solutions, particularly those with reduced clinker content in favor of mineral additions, appears to be a promising solution for improving the environmental performance of buildings. However, their usage in demanding applications — such as shotcrete placement — raises additional challenges, including their fresh-state behavior, hydration kinetics, and compatibility with existing chemical admixtures.

This lack of field performance knowledge hinders the acceptance and use of these binders on construction sites, thereby limiting their potential for carbon emission reduction. Consequently, a more detailed understanding of the mechanisms involved in shotcrete placement using low-carbon binders is required by our industry. Academic research can provide answers based on rigorous experiments conducted in a controlled environment, with the objective of ensuring the highest possible level of reproducibility.

To achieve this goal, the Université Laval Shotcrete Laboratory has acquired an innovative device: A small-scale wet-mix concrete spraying pump. This *LabSprayer*, developed and provided by Normet, differs from traditional spraying equipment in its ability to spray small quantities of mortar while allowing precise control of the dosage of rapid-set accelerating admixtures injected at the nozzle. It provides the flexibility of small batches (3.2 gal / 12 l), while combining all the elements of high velocity placement. This tool allows observation of mortar behavior under pressure, as well as its stability and texture during spraying. The experiments are reproducible, fast, and require only limited amounts of material. Consequently, the *LabSprayer* provides a

suitable framework for analyzing, comparing, and optimizing low-carbon binders.

Moreover, both American and Canadian standards governing portland limestone cement remain relatively permissive and allow a wide range of limestone contents, qualities, origins, and particle size distributions. This variability can lead to significant differences in the fresh-state behavior of concrete before, during, and after placement. A focus will be placed on rheology, with the aim of assessing the influence of particle size distribution and the cement grinding process on granular arrangement mechanisms. The objective is to study mortar using the *LabSprayer* and to gain insight into the expected behavior of concrete when processed with an industrial wet-mix pump.

The research project is conducted in collaboration with industrial partners who provide a variety of cements and admixtures currently available on the market, thereby ensuring that the materials studied are representative of those used in construction.

The project is in its exploratory phase, during which various binders and set accelerators are tested to help define the system's limits and capacity. For the various samples prepared, calorimetric testing is conducted to track hydration kinetics and evaluate the effects of admixtures on early-age reactions for a given binder type. Mechanical strength development is also monitored through early-age compressive strength tests. The combination of these results enables highlighting the relationship between hydration heat and strength development and defining a range of formulations compatible with the expected performance requirements of a project.

The main objective of this study is to define accelerator



**LabSprayer:** Two funnels are visible. The grey funnel connects to the larger cylinder for mortar, and the black funnel connects to the smaller cylinder for admixtures. The mixing between the mortar and the air-accelerator blend takes place in the nozzle at the end of the hose, visible in the picture.

dosage strategies that balance operational performance with the reduction of environmental footprint in wet-mix shotcrete. Specifically, the aim is to precisely determine the minimum quantity of accelerator required to achieve setting times compatible with shotcrete application, while ensuring the development of mechanical strength that satisfies performance requirements. In parallel, the carbon footprint is evaluated globally, accounting for both cement and admixtures. This approach seeks to provide the scientific basis necessary for the reliable implementation of portland limestone cement in shotcrete, an essential condition for its adoption and the realization of the potential reduction in the environmental footprint.

## **MARK JOLIN'S (DEFFOREY'S PROFESSOR) RECOMMENDATION FOR THE SCHOLARSHIP**

*Elsa is an exceptionally bright and capable graduate student, driven by curiosity and a talent for experimentation. The project she has undertaken in the Shotcrete Laboratory at Université Laval is the first of its kind. She is using a small-scale wet-mix shotcrete pump to evaluate how well modern cements and binders perform in wet-mix shotcrete applications. Her work focuses particularly on binders containing supplementary cementing materials and various fillers, tested both with and without set-accelerating admixtures, to assess their pumpability and early-age strength behaviour. Ultimately, her goal is to propose practical guidelines for engineers and practitioners who face challenges in the field.*