2021-2022 Awardee

Sophie-Isabelle Dionne-Jacques is a M.Sc. *Student in the Department of Civil and Water Engineering at Université Laval. The core of her graduate studies is to develop an integrated model of shotcrete rebound. This goal is to be achieved by further explaining the effect of rheology in substrate behavior during impact of aggregate. Her years of experience as a research assistant allowed her to develop concrete skills that she now builds upon to realize her M.Sc. project. She was a winning member of the concrete canoe project and the CAPSTONE design competition. She received her bachelor's degree in civil engineering from Université Laval.*

Nomination for the scholarship for Dionne-Jacques came from Marc Jolin at Université Laval. Jolin's recommendation included the following: "Sophie-Isabelle is a young M.Sc. student who started working in the Shotcrete Laboratory Université Laval, Québec City, Canada over two years ago, initially as a young undergraduate student helping out on shotcrete projects and now (since May 2021) conducting her own M.Sc. project on shotcrete placement optimization. Only a few days into her first shotcrete experiences, she demonstrated an impressive curiosity and a rigorous mind in the way she wanted to understand and improve shotcrete. Her M.Sc. project is the first hybrid project where the precision of automated shotcrete placement is capitalized on to further our understanding and description of rebound and precisely test the effect of combinations of rheology modifiers on rebound. In parallel, she is also preparing a unique paper integrating the most recent observations on rebound and earlier theories for what should be a reference paper for years to come."

DIONNE-JACQUES'S RESEARCH PROJECT

Rebound in Shotcrete: A New Predictive Approach

Rebound has been a major waste-related issue to the spraying process for years. The economic, environmental and efficiency losses related to it have yet to been solved.

The shotcrete research group at Université Laval has, over the years, focused its projects on three main paths to reduce rebound: optimization of the material, the equipment, and the technique. Since the first rebound theory proposed by Armelin in 1996[1], very few improvements have been added. However, the many studies on mixture designs and more recently, on the shotcrete material stream (velocities and special material distribution), have brought to light very interesting and important elements regarding the behavior of the concrete material within the stream and its impact on the substrate[2, 3].

Even with numerous research projects on mixture optimization, there are still no clear boundaries to identify the lowest rebound mixtures possible.

Therefore, it's important to further our understanding of rebound in order to design the most efficient mixture, select the best equipment and use an appropriate placement technique.

OBJECTIVES

To be able to complete Armelin's rebound theory, the project is organized around the following three objectives:

1. **"Zero-rebound" goal**
   This objective is intended to develop an optimized and high environmental added value mixture for the shotcrete industry with zero-rebound.
   Mixtures will be studied for their rebound results but also for their rheological and mechanical properties. A variety of additives and supplementary cementitious materials will be combined to ultimately obtain the perfect mix. The variation of dosages will be studied according to their effect on the rheological properties and consistency[4].
2. **"Small-scale" goal**
   The small-scale goal seeks to establish a relationship between the rebound for a mortar-type mixture and a shotcrete mix, according to the ACI 506R-165 aggregate size distribution #1 and #2 respectively.
   The use of small-scale shotcrete is relevant in experimental testing since it needs less material to characterize a single mixture. The ease of operation of small-scale equipment allows a greater range of mixtures to be tested and analyzed in a short amount of time.
3. **"Rebound rheology" goal**
   The cornerstone and most fundamental aspect of the project, this goal is aimed at truly incorporating the rheological portion of the substrate during spraying, including the effect of the incoming particles. This step will establish the parameters of the fluid zone of the receiving surface (substrate) and the rebound values within its borders.

RESEARCH SIGNIFICANCE

A new rebound model will provide a better understanding of the behavior of shotcrete and therefore offer more parameters to define the rules shotcrete mixture design. This allows the shotcrete mixture design to be optimized, making it possible to tailor the mixtures to the specific needs of the customer and application.

Ultimately the results of this project will provide general methods to increase the efficiency of mixture composition and elaboration of testing plans.

REFERENCES

[1] H. S. Armelin and N. Banthia, "Development of a general model of aggregate rebound for dry-mix shotcrete- (Part II)," Materials and Structures, vol. 31, pp. 195-202, 1998.

[2] A. Laradh, "Mise en place, énergie et rebond dans le béton projeté," 2020.

[3] N. Ginouse and M. Jolin, "Mechanisms of placement in sprayed concrete," Tunneling and Underground Space Technology, vol. 58, pp. 177-185, 2016.

[4] M. Jolin, D. Beaupré and S. Mindess, "Tests to characterise properties of fresh dry-mix shotcrete," Cement and Concrete Research, vol. 29, no. 5, pp. 753-760, 1999.

[5] ACI Commitee 506, Guide to shotcrete, Farmington Hills, Michigan: American Concrete Institute, 2016.