2018-2019 Awardee

Antoine Gagnon *is a PhD Student in the Department of Civil and Water Engineering at Université Laval, Québec City, QC, Canada. The focus of his graduate research is in developing tools for the design and testing of fiber-reinforced shotcrete (FRS) for ground support. Gagnon has worked on shotcrete research projects with different companies in the industry. He also serves on technical committees of the American Concrete Institute. He received his bachelor's degree and his master's degree in civil engineering from Université Laval.*

Nomination for the scholarship for Gagnon came from Marc Jolin at Université Laval. Jolin's strong recommendation included the following: *"I have decided to nominate Antoine Gagnon, this time for his PhD project, for the quality of his dossier and the outstanding leadership and contribution he has offered to the shotcrete industry so far. Already 2 years in his PhD, Antoine has reached the position of Chair of ACI Subcommittee 506-B, Shotcreting-Fiber-Reinforced, where he has managed to jump-start the work of the committee. He is also Secretary of the WP-24 of the Rock Technique Centre, working on a document titled, "Guideline on the Applicability of Fibre-Reinforced Shotcrete for Ground Support in Mines." And if that is not enough, Antoine has also been doing a 96-month internship with the Australian Centre for Geomechanics (at the University of Western Australia). During this internship, he has made the case for high-quality shotcrete and nozzleman certification on many occasions and he is responsible for opening up many opportunities in R&D collaborations. It should be noted that all these extracurricular activities have been conducted while leading a strong PhD research program that will, in short, help better understand the potential of FRS and how to test and specify them."*

GAGNON'S GRADUATE RESEARCH

Design and Testing of Fiber-Reinforced Shotcrete (FRS) for Ground Support

FRS has been used for many years in the tunneling and mining industry. This composite is used as part of ground support programs to help control the movements of the ground, therefore maintaining the structural integrity of the excavation. This is becoming critical as mines reach deeper levels where seismic activities and high stresses are the source of dynamic events such as rock bursts.[1] These powerful events are known to be unpredictable, which makes them particularly dangerous. Unfortunately, our current knowledge and understanding of FRS make it difficult to use at its fullest, especially under dynamic loads.[2]

However, FRS and ground support programs are of great importance in underground activities, as they control productivity while protecting workers and equipment. Indeed, it is a construction method that can be deployed easily and rapidly. Therefore, it is crucial to investigate this issue and optimize the use of FRS in underground activities.

Objectives

In this context, the research project will work toward answering the general question: How can we take advantage of the full potential of FRS, especially under dynamic loads? To answer this main question, the project will focus on three specific objectives:

1. **Show the differences in the FRS performance measured with current test methods**
   Up to 20 different FRSs will be tested with five different ASTM and EN test methods to better understand how each test represents the behavior and performance of an FRS mixture. The idea is to identify how test methods can be better adapted to certain contexts and why. Interesting preliminary results have already been published in Gagnon and Jolin.[3,4]
2. **Develop numerical analysis models to compare the potential of current test methods**
   Using a finite element modeling (FEM) software such as ABAQUS and previous fiber-reinforced concrete models, the data generated in the first phase will be compared in numerical models to confirm the previous conclusions and extend to new FRS mixtures. This will also highlight the significance of proper tuning for test methods under closed-loop control such as ASTM C1609 and EN 14651.
3. **Develop high-toughness FRS mixture designs for dynamic loads**
   In a parallel project, several different fibers have been tested to evaluate their behavior in FRS. The results will be used to evaluate their potential in high-toughness mixtures. Using the selected fibers at high dosages and in combinations, new FRS mixture designs will be developed with a focus on the ductility and toughness of the composite material. The challenge of maintaining a level of fluidity with such mixtures can be overcome with the use of air-entraining admixtures.[5]

Ultimately, this research will contribute to a better understanding of the behavior of FRS. It aids creation of design tools for engineers and presents high-performance alternatives to the shotcrete industry. These contributions will provide a safer underground environment for workers, provide access to previously inaccessible areas, and improve productivity in mine production cycles. It will also lead to an optimal use of FRS—this means less wasted material and less pollution as material often needs to be shipped to remote mine locations.

References

1. Ortlepp, W., and Stacey, T., "Rockburst Mechanisms in Tunnels and Shafts," *Tunnelling and Underground Space Technology*, V. 9, No. 1, 1994, pp. 59-65.

2. Vandewalle, M., "The Use of Steel Fibre Reinforced Shotcrete for the Support of Mine Openings," *The Journal of The South African Institute of Mining and Metallurgy*, V. 98, No. 3, 1998, pp. 113-120.

3. Gagnon, A., and Jolin, M., "Specifying and Testing Fibre Reinforced Shotcrete: Advances and Challenges," *Shotcrete for Underground Support XIII*, 2017, Irsee, Germany.

4. Gagnon, A., and Jolin, M., "A New Approach for Fibre-Reinforced Shotcrete under Dynamic Loading," 8th International Symposium on Sprayed Concrete, 2018, Trondheim, Norway.

5. Jolin, M., and Beaupré, D., "Understanding Wet-Mix Shotcrete: Mix Design, Specifications, and Placement," *Shotcrete*, V. 5, No. 3, Summer 2003, pp. 6-12.