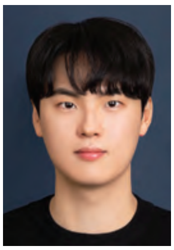
2023 – 2024 Awardee



Jongbeom Kim *is a Ph.D. candidate in the Department of Civil and Water Engineering at Université Laval, Québec City, QC, Canada. His primary research is focused on developing concrete mixture design and placement methods to reduce shotcrete rebound. He aims to characterize the dynamic properties associated with the freshly sprayed materials and establish a correlation to rebound. He earned both his Bachelor's and Master's degrees in Civil Engineering from Kangwon National University in South Korea. During his Master's studies, he focused on research evaluating the air-void structure and the freeze-thaw resistance of wet-mix shotcrete mixtures containing natural fibers. With years of experience in conducting dry-mix and wet-mix shotcrete experiments and collaborations with industry partners, he has a strong understanding of shotcrete.*

KIM'S RESEARCH PROJECT

Toward Zero-Rebound Shotcrete: Rheology Based Mix Design & Placement

Dry-mix shotcrete is especially adapted for concrete repair, characterized by minimal waste and immediate control over mixing water and mixture consistency. However, the phenomenon of rebound losses during placement poses both economic and environmental challenges[1]. To fully understand rebound, it is imperative that we explore the mechanisms governing the behaviour of the fresh shotcrete substrate upon the impact of the incoming aggregates. In this context, rheology emerges as an essential element in interpreting these interactions.

> "Rheology is used to describe and assess the deformation and flow behavior of materials"
> – Anton Paar[5]

Dry-mix shotcrete introduces specific challenges when it comes to rheological measurements. While classical concrete rheological models, like the Bingham model, offer substantial insight into the material's specific properties, they fall short in accounting for the material's elastic deformation. A more pressing concern is that the equipment presently available for measuring rheological parameters is not adapted for concrete that exhibits little to no slump. Hence, alternative methods for evaluating rheology of fresh, dry-mix shotcrete must be developed.

Recent studies have put forward the existence of a *fluid zone on the substrate* that is present during placement (Laradh, 2020[2]; Paquet, 2021[3] and Dionne-Jacques, 2023[4]). This fluid zone has been observed on the substrate surface during shotcrete placement and is located directly under t he spray of impacting materials. It exhibits unique placement mechanisms, which in turn play a significant influence over the phenomenon of rebound. In parallel, utilizing automation placement, shotcrete trials are more consistent and

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minimize errors. This approach is crucial to allow for a sound comparison of different mixture designs.

OBJECTIVES

The main objective of the project is to achieve *zero rebound* in dry-mix shotcrete. To reach this goal, the research project is structured around the challenges and a specific research avenue that aims to address these questions systematically:

(1) Is it possible to validate the hypothesis concerning the existence of a fluid zone in the substrate of dry-mix shotcrete? Can it be also characterized?

(2) Can the properties of the fluid zone be controlled and modified to further reduce rebound? Further, can it be controlled and modified while maintaining adequate hardened shotcrete properties for long-term durability?

(3) Based on the newly acquired dynamic properties, is it possible to investigate the impact of different spray angles, or other spraying parameters, on rebound efficiency?

In answering the above questions, the approach to addressing the project-specific objectives is described as follows:

i) Create a tool or method to validate a *fluid* zone and characterize the dynamic properties of dry-mix shotcrete *during placement*.

ii) Explore and incorporate admixtures to create appropriate *fresh shotcrete dynamic properties (a rebound-friendly fluid zone)* to reduce rebound while maintaining proper hardened shotcrete properties.

iii) Adjusting spray angles to test dynamic properties in the lab is not reasonable. *Modeling* will be utilized to understand the impact of different spray angles on rebound efficiency.

By discovering how admixtures influence the dynamic penetration stress and its correlation with rebound, and developing a mixture design that achieves *zero rebound*, a significant reduction in material wastage can be realized, thereby, enhancing economic efficiency. Such advancements have the potential to make substantial contributions to the shotcrete industry and future shotcrete R&D work.

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