The Eglinton LRT: How to Make a Big Impact with a Smaller Carbon Footprint

by Stacia Van Zetten and Jolene McLaughlin

The Eglinton Crosstown Light Rail Transit (ECLRT) is part of Metrolinx's regional transportation plan, The Big Move, and is one of the first large-scale transit projects for the Toronto, ON, Canada area. ECLRT will provide fast, dependable, and comfortable transit along Eglinton Avenue, helping to reduce congestion while integrating transit services.

Since January 2014, a joint venture (JV) known as Crosslinx Transit Solutions Constructors (CTSC) and comprised of EllisDon Corporation, Aecon Group Inc., ACS – Dragados, and SNC Lavalin Group Inc., is responsible for the project design and construction. Upon completion, ECLRT will connect east and west Toronto with 25 stations along a dedicated route, helping users cross the city 60% faster than by bus or car.

The completed project will contribute to reducing significant greenhouse gas (GHG) emissions by taking cars off the road and lessen the need for diesel buses. In addition, the project provided opportunities for further GHG emissions reductions during the construction process.

The project required over 500,000 m^3 (654,000 yd^3) of concrete (the equivalent of about 200 Olympic-size swimming pools) across the 25 stations and stops, tracks, signals, communications system, as well as a maintenance and storage facility. Concrete, with the constituent component cement being responsible for 8% of the world's GHG emissions,[1] has a significant carbon footprint. Therefore, reducing the emissions from the project's concrete provides a significant reduction potential in GHG emissions.

CTSC invested in valuable research to identify optimization opportunities in the concrete mixtures to maximize long-term durability of the massive placements while reducing carbon emissions. The use of a high-volume supplementary cementitious material (HVSCM) combined with state-of-the-art concrete sensor technology (EXACT Technology) helped the team meet the objectives for resilience and reduced emissions.

Increasing the Amount of Allowable SCM

The ECLRT project's concrete specifications included stringent requirements for maximum temperature and maximum temperature differentials to minimize thermal cracking of structural elements. CTSC enlisted EllisDon's Construction Sciences team to review the specifications and provide a thermal control plan for the project. A key mandate of the plan was to increase the amount of allowable supplementary cementitious materials (SCMs), which would reduce the heat released during the hydration process by reducing the portland cement content. The JV team invested in comprehensive testing to evaluate the SCM, in this case slag cement, at replacement levels ranging from 10 to 80% to understand the durability and performance impacts of decreasing the cement content. Results from the study, in combination with data from Europe and other jurisdictions, showed that the SCM at a 70% replacement value was optimal. Figure 1 shows the effects of various replacement levels on the heat of hydration and overall temperature rise through the curing process.[2]

The significant amount of mass concrete employed on ECLRT required careful consideration to manage the heat generated during the curing process. Codes and standards specify mass concrete elements as anything at least 1 m (3.3 ft) thick or elements subject to significant thermal stress, such as the finished walls and slabs at many of the stations, as shown in Fig. 2. All mass concrete mixtures generally have some percentage of SCMs to aid in heat reduction during the curing process. Until recently, this was often limited to less than 50% of SCMs; it is typical for specifications on projects similar to ECLRT to still carry this limit. However, because of the sheer volume of the mass elements for ECLRT, the SCM increase was critical to manage the internal heat gained during hydration and curing. Collaboration among CTSC, concrete suppliers, and Metrolinx was required to enable the use of an increased volume of SCM at what is considered high volumes.

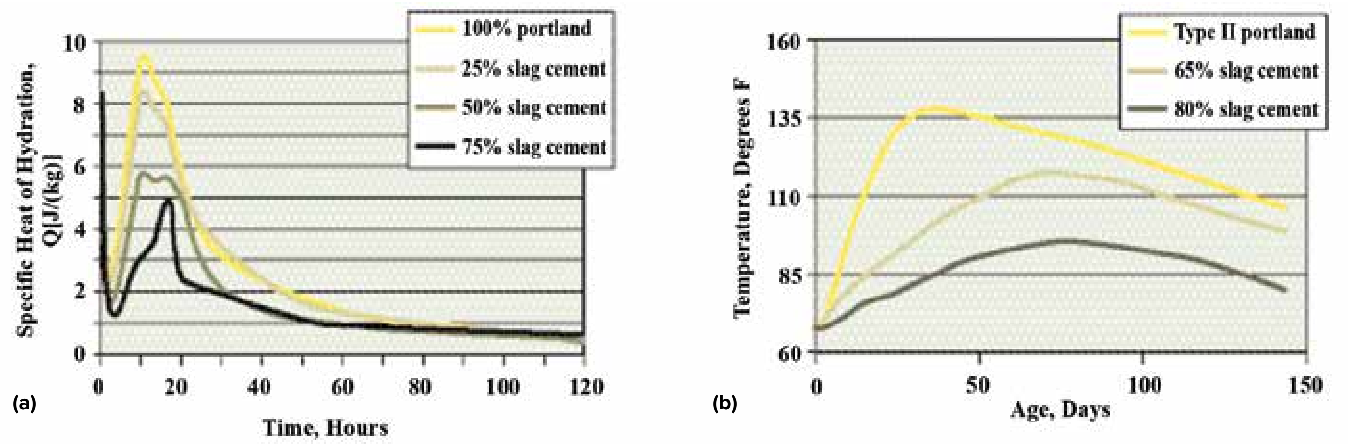

Fig. 1: Effect of slag cement on mass concrete: (a) heat of hydration; and (b) temperature rise[2]

Fig. 2: Multiple mass concrete placements at Eglinton LRT Station

Fig. 3: Temperature monitoring equipment was installed shortly before concrete placement

The main project sponsor and overall owner of the project is Metrolinx; however, Infrastructure Ontario (IO) and the Toronto Transit Commission (TTC) are significant stakeholders in the project. As major public agencies, these organizations must consider the public safety and future maintenance of the project assets in their evaluation of any proposed innovations. An increase of the allowable SCM percentage in the design is only possible if it will not compromise the integrity of the project requirements as stipulated in the specifications. To support this, CTSC invested in further research, evaluating the impacts of various SCMs at a wide range of volumes to verify the impacts of changing the mixture designs. Ultimately, by working with the concrete suppliers, subcontractors, and the various stakeholders, CTSC confirmed that 70% replacement using slag cement was the optimal level to ensure the project would achieve its durability and performance requirements. After thorough investigation and verification of the performance of the HVSCM mixtures, all stakeholders agreed to increase the SCM use in most of the mass concrete elements.

Monitoring and Match Curing

Throughout the process, CTSC has used EXACT Technology (Fig. 3) to monitor the mass concrete placements, ensuring that the placements remain within the specified limits for maximum temperature and maximum temperature differential. Project teams were able to access critical data online on a 24/7 basis to make educated decisions for thermal control (for example, adding or removing thermal blankets or providing supplementary heat to the placed concrete as it cures) resulting in the most efficient element turnover.

EXACT's temperature sensors are also used to monitor in-place strength using maturity calculations as well as by communicating with remote curing boxes with strength test cylinders. In the latter application, the system allows the cylinders to experience the same temperatures as those resulting from the heat of hydration of the mass concrete placements. As a result, project teams can observe and monitor the higher concrete temperatures at early ages and rely confidently on highly representative strengths to advance critical activities, such as removing formwork or loading the elements. This offers contractors more control over the curing/

strengthening timelines resulting in optimal material use while achieving performance requirements without the added costs from having to apply additional heat during curing.

Benefits of Using HVSCM

SCMs are commonly used in concrete mixtures for everything from foundation walls to bridge decks. Mixtures with cement replacement levels exceeding 40% are considered HVSCM. Employing HVSCM not only results in more durable concrete that is less susceptible to temperature-driven compromise during hydration, but it is also significantly better for the environment because it greatly reduces concrete GHG emission intensity.

As with all materials, the GHG emissions intensity of any concrete mixture depends on the emissions intensity of each constituent. Emissions estimates presented in this article for the HVSCM mixtures used at ECLRT as compared to lower SCM replacement mixtures are based on current best practices and industry average emissions rates for concrete components as published in the Canadian Ready Mixed Concrete Association's (CRMCA's) environment product declaration (EPD) report.[3] Figure 4 shows the impact to GHG emissions, specifically global warming potential (GWP), measured as carbon dioxide equivalents (CO_2e) when portland cement is replaced with SCMs.

By using 70% SCM (slag cement), CTSC was able to eliminate nearly 130,000 tonnes (143,300 ton) of CO_2e as compared to using a mixture with cement only. While all mass concrete mixtures have some percentage of SCM to aid in temperature control, the impact of increasing the volume of SCM is still significant. For context, the emissions reductions realized here are roughly the same magnitude as taking more than 28,000 passenger vehicles off the road for a year.

Environmental Savings with HVSCM

As Canada looks to meet aggressive emissions reduction targets, finding ways to reduce emissions in the concrete we use to build our cities and support systems is critical. The industry is investing in process improvements, including new technologies, to drive toward a zero-emission material. In the meantime, using HVSCMs and accurate monitoring tools can help realize meaningful incremental reductions.

Procurement authorities at all levels of government should focus on performance-based specifications that outline durability, structural integrity, and GWP limits while encouraging innovation. This will encourage market adoption of tools that will ensure adherence to performance requirements while reducing GHG emissions.

Over the coming decade, the U.S. and Canadian governments are poised to commit nearly three-quarters of a trillion dollars on large infrastructure projects comparable to the scope and magnitude of ECLRT. If these projects employ HVSCM, the resulting environmental benefits will be staggering—estimated carbon savings roughly the same amount as taking about 1.7 million passenger vehicles off the road for an entire year! HVSCM adoption across major infrastructure projects globally will deliver more robust infrastructure to the world at a fraction of the environmental cost while also improving the performance characteristics.

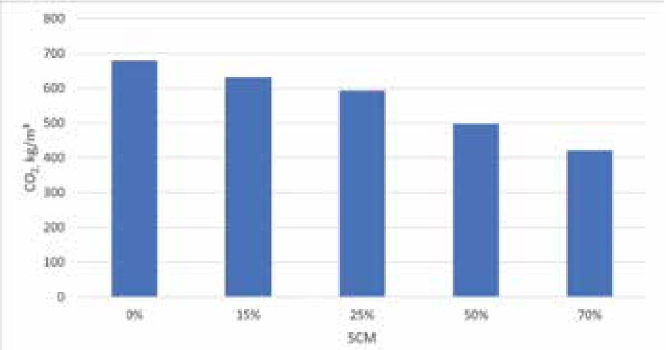

Fig. 4: Reductions in CO_2 emissions for various SCM contents in concrete mixtures. Calculated values are based on ZGF LCA Tool and the CRMCA industry average EPD (Note: 1 kg/m^3 = 0.06 lb/ft^3)

References

1. Lehne, J., and Preston, F., "Making Concrete Change: Innovation in Low-Carbon Cement and Concrete," The Royal Institute of International Affairs, Chatham House, London, United Kingdom, June 2018, 122 pp., www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete.

2. "Reducing Thermal Stress in Mass Concrete," Slag Cement Association, Farmington Hills, MI, 2013, 2 pp.

3. "CRMCA Member Industry-Wide EPD for Canadian Ready-Mixed Concrete," Canadian Ready Mixed Concrete Association, Mississauga, ON, Canada, Jan. 6, 2017, 24 pp.

Selected for reader interest by the editors.

Stacia Van Zetten is the Chief Strategy Officer and Co-Founder of EXACT Technology. She is a structural engineer and has over 10 years of experience with a focus on concrete materials and construction. She serves on several committees of ACI, the International Concrete Repair Institute, and the Canadian Standards Association

Jolene McLaughlin has spent more than 12 years driving sustainability initiatives across various segments of the built environment. In her role as Director, Corporate Sustainability for EllisDon Corporation, she works to build partnerships across the industry that support carbon emissions reductions throughout the value chain, from the materials used to onsite processes.