2020 RESEARCH PROJECT STATEMENT

Research Topic:
Extending Service Life of Concrete Sidewalks Exposed to Extreme Weather Conditions through Internal Conditioning and Improved Workmanship
[Research Award – max $180,000]

Problem Statement and Objectives

Deterioration, such as scaling, of concrete sidewalks is one of the most urgent challenges that need to be tackled. While extensive research efforts, including the incorporation of chemical and mineral admixtures, modified mixture design and curing treatment, have been performed, there still exist significant gaps and issues in developing truly durable concrete. MassDOT is seeking to improve the quality and durability of concrete to address the statewide deterioration challenges of the currently used concrete sidewalks under the extreme weather conditions of Massachusetts with an objective to reduce the significant maintenance and reconstruction costs. Considering the aging mechanisms of concrete sidewalks in Massachusetts, there are several potential causes:

(i) Freeze-thaw cycles during the frosty weather: It is known that concrete is a porous material and the tiny pores in concrete are typically filled by water due to rain, snow and the capillary suction of water from sub-grade. At a degree around -8°C (17.6°F), the pore water freezes with a volume expansion of 9% producing internal pressure to concrete. The accumulative effect of successive freeze-thaw cycles and disruption of cement paste and aggregate can eventually cause cracking, scaling and crumbling of concrete thereby leading to the end of the functional service life of sidewalks.
(ii) The use of deicing salts: Chloride-based deicers are commonly used to melt ice and snow in winter by reducing freezing point, but the chloride can penetrate into concrete resulting in corrosion of steel reinforcement and deicing salt damage of concrete.
(iii) Non-optimized Mix Design
(iv) Workmanship and Improper curing methods and procedures

The coupling effects between these two strain-based concrete degradation mechanisms along with over-working or abrasion have been rarely investigated. Therefore, there exists a critical need to study the degradation behavior of concrete in the presence of the coupled attacks and to develop durable concrete to address these challenges. In pursuit of this strategic goal, developing an applicable and cost-effective technology to improve the intrinsic degradation resistance of concrete deserves our full attention.

The overall research objective of this project is to develop an internal conditioning technique to design durable concrete sidewalks with high scaling resistance, low

permeability and extended service life in the presence of harsh weather conditions and deicing salts. This project will seek to:

1. Optimize concrete mix designs
2. Investigate proper workmanship and curing methods and procedures
3. Determine if the curing method currently specified at MassDOT is effective
4. Explore if there is a curing compound more or less effective than the 3-day moist cure
5. Identify how long after the concrete has been placed that it can be finished
6. Determine if penetrating sealers are effective at limiting chloride penetration from commercially available chemical deicers.

Anticipated Outcomes and Deliverables

- Development of internal conditioning based on reactive mineral additives as an innovative bottom-up approach for performance-based concrete design
- Investigating the influence of internal conditioning on cement hydration and its subsequent effect on durability-related properties, including microstructure, workability, permeability, mechanical and transport properties, and in particular scaling resistance
- Validation of concrete sidewalk's resistance against freeze-thaw cycles combined with deicing salts and surface abrasion through laboratory accelerated aging treatment and field tests.
- Optimization of concrete mix designs
- Improvement of workmanship, curing methods, current standard specifications with additional language regarding placement, finishing, and length / type of curing method
- Recommendation on whether or not penetrating sealers should be included in our standard specification for sidewalks