Research Brief

Wisconsin Highway Research Program
Project 0092-19-03
October 2021

Single-Slope Slip-Formed Concrete Barrier Design and Performance

Research Objectives

- Determine the main types of concrete distress observed in single-slope slip-formed concrete barriers
- Investigate the causes and sources of distress in these barriers
- Develop strategies for improving WisDOT's barrier practices

Research Benefits

- Identified opportunities for improving performance and cost-effectiveness of single-slope slip-formed concrete barriers
- Recommended improvements to barrier material, construction and inspection practices to reduce the need for maintenance or replacement

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Background

Single-slope slip-formed concrete barriers are traffic barriers with a uniform angle constructed on site by a slow-moving machine that continuously feeds concrete over preplaced rebar. These barriers can be built rapidly and economically and are not affected by changes in road height after repaving. However, the Wisconsin Department of Transportation (WisDOT) has found that single-slope slip-formed barriers along Wisconsin roads deteriorate at an advanced rate. Factors that may affect the durability of concrete barriers include composition and quality of the concrete; level of exposure to deicing solutions; stresses induced by volume changes due to shrinkage or temperature variations; and construction procedures.

Premature deterioration reduces barriers' ability to withstand vehicle impacts and necessitates added maintenance or replacement. The objectives of this research were to investigate the causes and sources of these distresses and develop strategies to ensure better long-term performance of single-slope slip-formed barriers in Wisconsin.

Methodology

The research team visited four locations across the state – one each in the northwest region (NW-1) and southwest region (SW-1) and two in the southeast region (SE-1 and SE-2) – to investigate crack spacing, length and width. Areas with visible distress were evaluated through visual inspection (VI), ultrasonic pulse velocity (UPV), half-cell potential (HCP) and ground penetrating radar (GPR).

Ground penetrating radar is used to locate rebar within barriers.

Core samples extracted from each site were used to examine the type and quality of the aggregates, to identify the presence of alkali-silica reaction, and to measure the stiffness and strength of the concrete. In addition, powder samples of the concrete within ½ in. to 1 in. in depth were extracted to determine the chloride-ion content in the barrriers.

"This research outcome helps WisDOT identify the main reason of premature deterioration of single-slope slip-formed concrete barriers. The findings will improve the quality of the concrete barriers by enhancing the construction and inspection process and improving material selection."
– Myungook (MK) Kang, WisDOT

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Final report is available at:
WisDOT Research website

Results

The primary distress type found in this study was vertical cracking which was found in all inspected barriers. Minor spalling and map cracking were also found in some cases. The crack widths in barriers NW-1 and one section in SE-1 did not appear to affect structural integrity; however, the severity (quantity and size) of cracking in barriers SE-2 and SW-1 indicated the potential for reduced structural integrity in portions of the segments evaluated in this investigation.

The depth of concrete cover placed over rebar exceeded specifications by up to 100% (two inches) in some cases; this can increase crack widths on the surface by 20 percent. The cement content used in barrier SE-2 was much higher (480 lbs/yd^3) than the specified value of 395 lbs/yd^3, another possible cause of its excessive number and size of the cracks.

GPR and UPV measurements of each barrier did not indicate voids or poor consolidation, suggesting there was not widespread deterioration of stiffness or strength of the concrete. Locally, however, cores extracted from barrier SE-2 showed evidence of voids and poor consolidation. This is further evidence that the concrete used in this barrier was of substandard quality. There were no signs of alkali-silica reaction in the barriers.

Recommendations for implementation

WisDOT can better capitalize on the performance and cost improvements of single-slope slip-formed barriers by improving material, construction and inspection practices. The research team delivered the following recommendations for achieving these goals:

- Control concrete hydration by using low heat cement or admixtures; curing the concrete immediately after placement; and using insulated blankets to limit the difference between internal and external temperatures to 30°F or less .
- Use well-graded coarse aggregates no larger than ¾ inch, and avoid gap-graded gradation with larger coarse aggregates.
- Increase the reinforcement-to-concrete ratio to 0.005-0.0055.
- Adhere to the specified concrete cover.
- Tighten the tolerances for rebar placement and spacing.
- Improve inspection and quality control during construction.
- Improve data collection during and after construction.

This brief summarizes Project 0092-19-03,
"Evaluation of Roadway Concrete Barriers and Materials"
Wisconsin Highway Research Program