Research Brief

Wisconsin Highway Research Program
Project 0092-23-05
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Underwater Concrete Pours and Non-Segregating Concrete

Objectives

- Examine best practices for the placement of concrete underwater and in deep drilled shafts
- Evaluate current guidance and specifications for improvements based on best practices

Benefits

- Enhances existing WisDOT policies, standards and specifications regarding underwater concrete placement or repair for bridge substructures
- Minimize environmental impact while ensuring the concrete's quality and structural integrity

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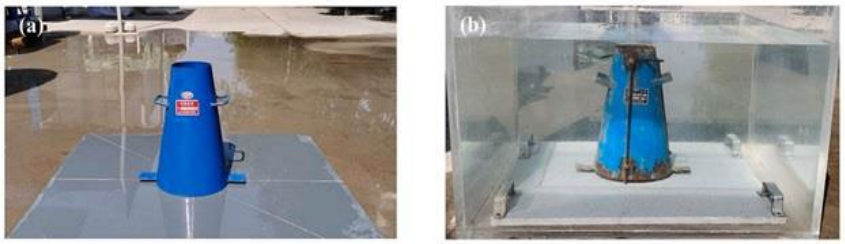
Background

Underwater concrete (UWC) placement in bridge substructures often raises concerns regarding concrete quality, primarily due to the potential for aggregate segregation, especially in deep drilled shafts. Such issues are not only challenging to identify but also include substantial repair costs. The overarching goal of this project was to critically evaluate and recommend enhancements to existing WisDOT policies, standards, and specifications regarding underwater concrete placement or repair for bridge substructures and the prevention of aggregate segregation during concrete placement in deep drilled shafts.

Methodology

Relevant research studies and the practices of other departments of transportation (DOTs) and the construction industry, especially agencies and companies operating in marine settings, were explored. The research team examined numerous materials and construction-related factors involved in pouring concrete underwater or in deep drilled shafts, including parameters such as concrete mix designs and placement techniques.

Additionally, a nationwide survey was distributed to key personnel in 50 state DOTs to better understand current practices and trends, the difficulties faced by various DOTs, solutions to these challenges, and potential directions for the future.



Mock-up test assessing UWC flowability: (a) Slump flow test in the air and (b) Underwater slump flow test.

Results

The extensive research comprising a literature review, database analysis, and survey of practices, combined with input from various DOTs and experienced contractors who work in UWC and drilled shafts, has led to significant insights into UWC and drilled shaft construction. In underwater concrete placement, there is a consensus among numerous state guidelines regarding the initiation of the process.

"Underwater concrete pours are a critical technique for constructing bridge substructures. This research explores methods to mitigate associated risks and enhance concrete quality for these underwater structures." – James Luebke, WisDOT

It is generally agreed that concrete placement should only commence when the tremie or the designated placement apparatus has been accurately positioned at the correct base or shaft elevation. This precise positioning is essential to ensure a consistent and controlled flow of concrete, which is critical to achieving the desired structural integrity and durability. Adhering to this protocol mitigates the risks of premature washout and potential contamination of the concrete, thus laying a solid foundation for the subsequent phases of construction. The compiled guidelines from surveyed states show a consistent focus on quality assurance, equipment standards and placement conditions.

Recommendations for Implementation

As specifications are refined across all 50 state DOTs, the goal is to delve deeper into the specifics of materials, mix designs, and placement techniques. This will enhance the methods of direct underwater concrete casting, advancing practice with the accumulated wisdom of experience and the fresh perspective of innovation.

Based on the results, the research team provided several recommendations related to the mix proportions, as well as fresh and hardened properties of underwater concrete including:

- Grade A should be used for structural concrete, which contains a minimum cement content of 565 lb/yd^3. For specific applications, such as underwater concrete, an engineer-approved mix design with a potentially higher cementitious materials content is permissible.
- WisDOT specifies that the oven-dry weight of fine aggregates shall constitute up to 45% of the total oven-dry weight of aggregates in concrete mixtures, which aligns well with the recommended ranges. However, increasing the ratio to at least 50% can be considered for underwater concrete and drilled shaft applications.
- For structural concrete mixtures, WisDOT specifies the maximum size of aggregate to be 1 inch. WisDOT also recommends that well-graded coarse aggregates should conform to the ASTM C33 gradation requirements for size number 67 aggregates.

Interested in finding out more?
Final report is available at:
WisDOT Research website

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