Rowan University

CENTER FOR RESEARCH & EDUCATION
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Technical Brief

Cold Weather Concrete (CWC) for Structural Application

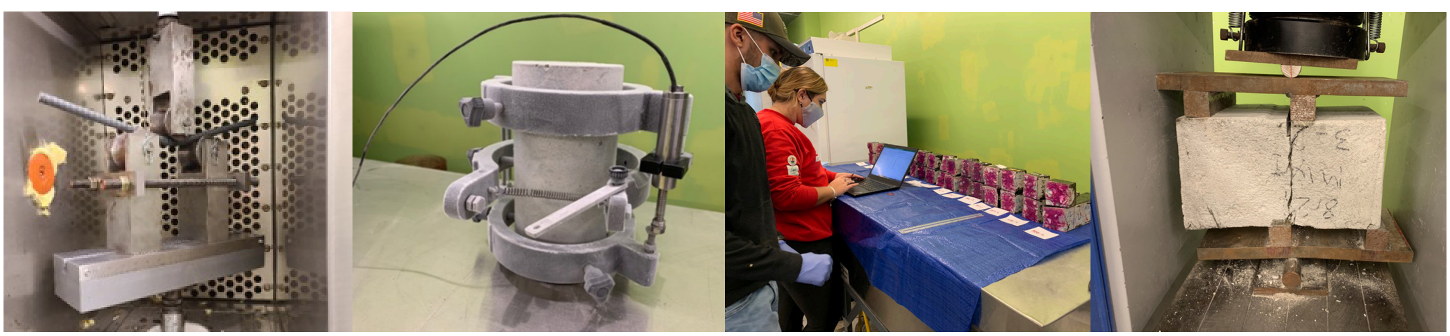
Background

The construction and service of reinforced concrete structures in regions subject to cold weather introduces complications at all life cycle phases, including initial mixing, curing, and service. One of the approaches to producing concrete at cold temperatures is to use additive-based freeze protection (ABFP). Using ABFP avoids the energy cost associated with heating and potentially extends the construction seasons. Additive-based freeze protection comprises combinations of admixtures that facilitate concrete's hardening and strength gain in cold weather without applying heat. This project investigates the mechanical and durability properties of cold-weather concrete with ABFP (CWC) that are mixed, cast, and placed at subzero. In addition, these concrete's mechanical properties are determined when tested at temperatures ranging from -76 to 28 °F (-60 to +20 °C).

Research Objectives

The project is a laboratory study to investigate the properties of concrete and reinforcing bars using ABFP for reinforced concrete structures subject to cold temperatures. The specific objectives of this research are:

1. Characterize the mechanical properties of concrete made with ABFP and reinforcement at temperatures ranging from -76 to 28 °F (-60 to +20 °C) for the design of reinforced concrete structures in cold regions, specifically: concrete compression, rupture, and shear strength
2. Characterize the corrosion potential of reinforcement in concrete with ABFP, specifically: chloride ion permeability and relative carbonation potential
3. Characterize the durability properties of concrete with ABFP, especially; freeze-thaw behavior and drying shrinkage.



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Summary of Findings

Results show that cold-weather concrete specimens manufactured at -5 °C are similar to room temperature control specimens for compressive strength, shear strength, drying shrinkage, and resistance to freeze-thaw cycles. However, CWC shows lower electrical surface resistivity and higher chloride ion permeability, which is likely due to the ionic solutions of cold weather admixtures. In addition, results also show that mechanical properties of concrete, such as compressive strength, elastic modulus, flexural strength, and shear strength, increase when the concrete testing temperature is lowered.

Direct Benefit to Military Engineering

The applicability of the current design practices for reinforced concrete structures in cold regions can be evaluated by investigating how the mechanical properties of concrete made with ABFP and various types of concrete reinforcement are affected by cold temperatures. In addition, validation of recommended changes to existing design practices (such as concrete reinforcement determination and member dimension) will allow appropriate structural designs for the given materials and climate.

The research can extend reinforced concrete's construction season to the winter months without requiring specialized equipment to protect the concrete during placement or curing. The increased construction season will improve the rate at which vital infrastructure construction projects can be completed.

The research will also allow the construction of reinforced concrete structural elements at cold temperatures without the energy-intensive procedures used in traditional cold weather concreting during mixing and curing, making construction operations on structures in cold weather more efficient.

Conclusions and Recommendations

Based on the results of the study, cold-weather concrete achieves adequate mechanical and durability properties required for structural applications. It also shows that mechanical properties such as compressive, flexural, and shear strength increase when concrete testing temperature is lowered. Temperature ranging from 68 to -76 °F (-60 °C) had effectively no effect on the yield and ultimate strength of A1035, where the yield and ultimate strengths of A955 increased by 15.4 and 15%, respectively, at -76 °F (-60 °C) compared to 68 °F (20 °C). Measuring the properties of reinforced concrete (composite) at different ambient temperatures was recommended for future work.

Related Publications

William T. Riddell, Douglas B. Cleary, Gilson R. Lomboy, Shahriar Abubakri, Danielle Kennedy, Benjamin Watts (2021). Reinforcing Materials at Cold Temperatures, The 2021 World Congress on Advances in Structural Engineering and Mechanics (ASEM21) GECE, Seoul, Korea, August 23-26, 2021.

William Riddell, Douglas B. Cleary, Gilson R. Lomboy, Shahriar Abubakri. Benjamin E. Watts, Danielle E. Kennedy, Brian Berry, Amelia Chan, Nicholas Giagunto, Joseph Goodberlet, Maximilian Husar, Joseph Kayal, Christopher McCormick (2022). Cold temperature effects on reinforced concrete structural behavior, Canadian Society for Civil Engineering (CSCE) Annual Conference, May 25-28, 2022, Whistler, BC

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More details about the study will be available at rowan.edu/creates

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