CRREL-ERDC

Technical Brief

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Cold-Weather Self-Consolidating Concrete

Background

Frost protection of cold-weather concrete traditionally relies on energy-intensive heating, raising both cost and CO_2 emissions. ERDC-CRREL previously developed an additive-based freeze protection (ABFP) system, a set accelerator and corrosion inhibitor, that eliminates the need for external heating by accelerating hydration and lowering concrete's freezing point. Separately, self-consolidating concrete (SCC) is highly flowable and non-segregating, spreading into place and encapsulating reinforcement without mechanical consolidation, making it ideal for heavily reinforced structures. SCC has been studied down to −0.5 °C, but its performance with ABFP-type accelerators under sustained subfreezing conditions has not been well characterized. This study develops cold-weather self-consolidating concrete (CWSCC), an SCC formulated with ABFP that withstands −5 °C (23 °F) without artificial heating, combining SCC's placement efficiency with ABFP's frost protection in a single solution.

Research Objectives and Approach

This research applies ABFP technology to create an SCC that maintains adequate fresh and hardened properties in cold regions under sustained freezing temperatures. Eighteen mixtures, mixed and cured at −5 °C (23 °F) and compared to conventional SCC at 20 °C (68 °F), tested the effects of the set accelerator and corrosion inhibitor, a hydration stabilizer, supplementary cementitious materials (fly ash and slag), and viscosity control agents (limestone powder or a viscosity-modifying admixture). Fresh properties, including slump flow, passing ability, segregation resistance, and rheological parameters, were tracked for 60 minutes after mixing; setting behavior was assessed by standard penetration resistance and an alternative ultrasonic pulse velocity (UPV) method; and compressive strength was measured through 90 days. A cost evaluation then compared vibrated concrete and heated SCC against unheated CWSCC across structures of varying size.

Direct Benefit to Military Engineering

CWSCC gives military engineers a material that combines two advantages traditional cold-weather practice cannot offer together: consolidation-free placement and heating-free frost protection. Understanding how CWSCC's fresh and hardened properties respond to low temperatures provides reliable guidance for adjusting mix designs and mixing procedures to ensure sound structural outcomes for military infrastructure in cold regions. The technology accelerates construction by enabling faster placement, valuable for urgent projects, and reduces reliance on the specialized equipment and manpower needed for consolidation and heating, lowering costs and shortening timelines. It also improves work safety by requiring fewer workers and less equipment, minimizing noise, and shortening construction activities in cold weather, particularly for rapid-entry and forward-operating construction where heated enclosures and fuel supply are impractical.

Conclusions and Recommendations

CWSCC is a viable cold-weather concreting solution: mixed and cured at −5 °C (23 °F) with ABFP, it holds workable fresh properties for 15 to 60 minutes and sets sooner than room-temperature concrete, with no artificial heating required. The main trade-off is strength, not workability, since air-curing at −5 °C lowers compressive strength relative to heated controls, and adding a hydration stabilizer or supplementary cementitious materials lowers it further, so these additives should be used cautiously in freezing conditions. Economically, CWSCC costs about 33% more in materials but cuts placement and consolidation cost by roughly 40% and eliminates heating cost entirely, making it the more cost-effective choice for smaller structures; savings shrink as structure size grows. Future work should widen the temperature range tested, vary water-to-cement ratio and admixture dosage, and evaluate additional hardened properties and CO_2 impact.

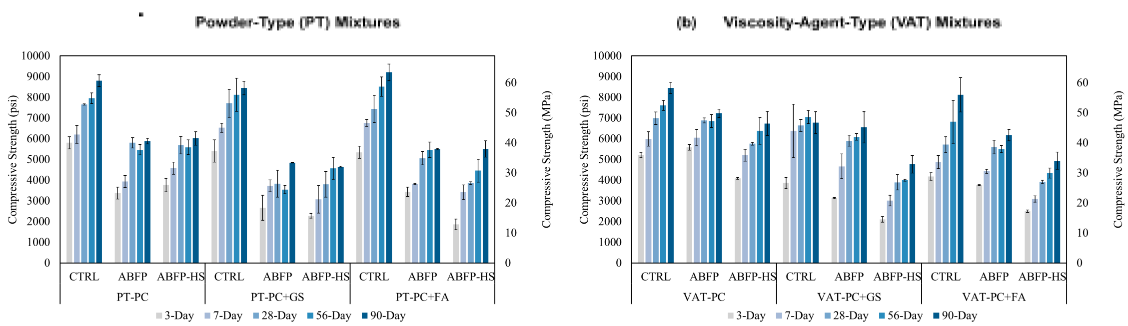

Figure 1. Compressive strength (3-, 7-, 28-, 56-, and 90-day) of CTRL, ABFP, and ABFP-HS mixtures with PC, PC+GS, and PC+FA binders: (a) powder-type (PT) mixtures using limestone powder as the viscosity modifier; (b) viscosity-agent-type (VAT) mixtures using VMA.

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