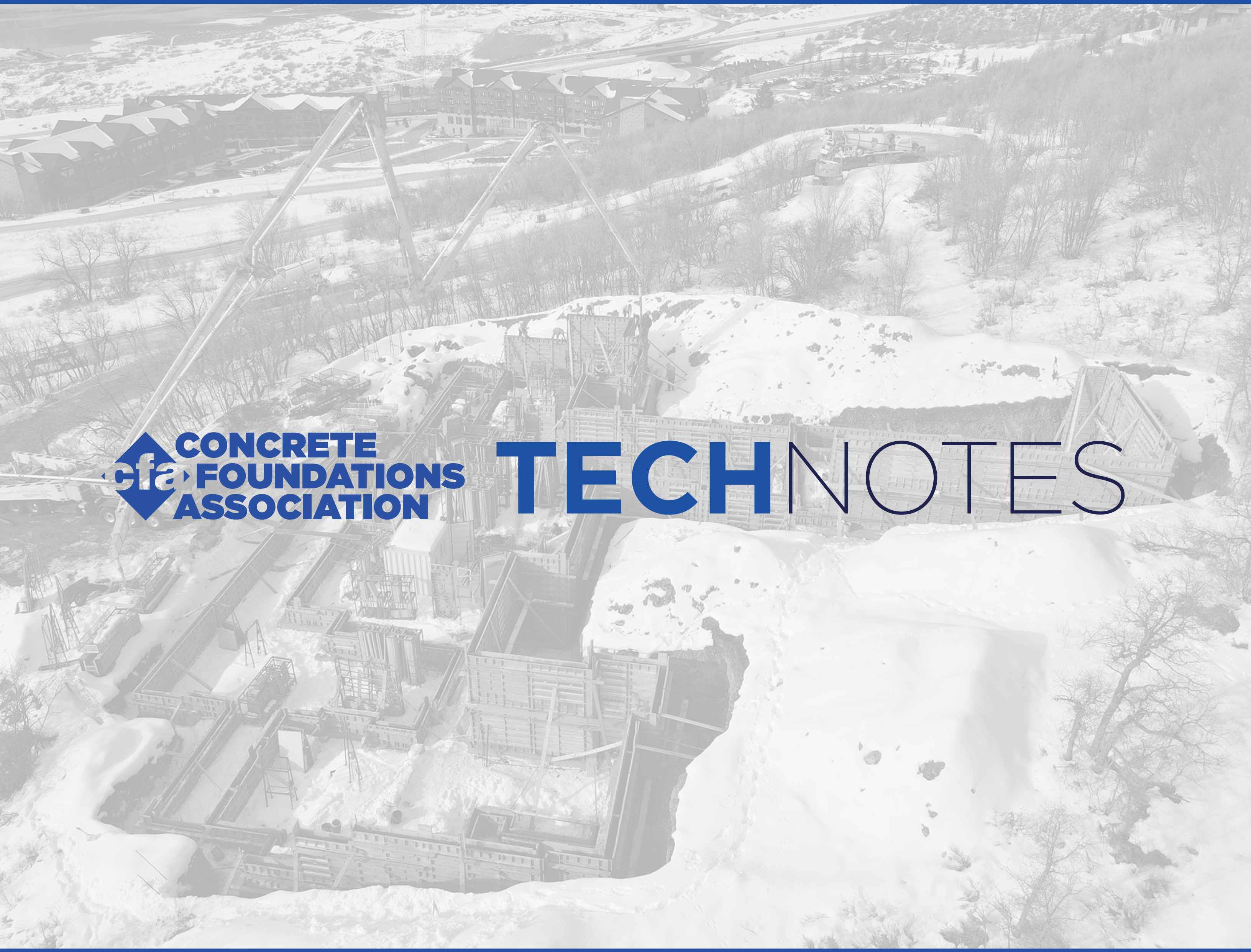

CONCRETE FOUNDATIONS ASSOCIATION

TECHNOTES

CFA-TN-003

Casting Residential Foundation Walls in Cold Weather

Casting Residential Foundation Walls in Cold Weather

Goal and Purpose

This edition of Tech Notes explains the practical implementation of the CFA Cold Weather Research completed in 2004. This research was undertaken with the goal of providing evidence for the performance of "real world" mixes that contractors regularly use and establishing the validation process by which variations in mix design can be evaluated and applied to foundation wall construction during cold to frozen conditions.

Codes and Perceptions

Code officials and builders often fear that concrete cast in ambient temperatures 40°F or less will be substandard, or even worse a failure if it freezes prematurely. Most national codes and standards, however, are not as alarmist on the subject. Requirements for Residential Concrete Construction (ACI-332-08) states "*...concrete temperature shall be maintained above a frozen state until concrete compressive strength of 500 psi has been reached.*" The CFA Standard makes a similar statement. However, some building officials often choose the more conservative directives of ACI's Standard Specification for Cold Weather Concreting (ACI-306.1-90), which prescribes stringent protection procedures and concrete temperature monitoring "*... when for more than three successive days the average daily outdoor temperature drops below 40°F.*" Following ACI-306 causes extra costs to the builder and consumer. Are such extra costs in residential construction worth it?

Empirical Experience and Evidence

Based on the experience of many CFA contractors, the cold weather mandates for protection procedures of blankets, tenting, and heating are often excessive in terms of both time and money. Using concrete mixes designed for freezing conditions, CFA concrete contractors have successfully poured thousands of concrete footings and walls, far exceeding design specifications, in freezing weather down to 10°F without any protection procedures.

The Research Project

In order to resolve the conflict between theory and practice, the CFA funded a cold weather concreting study to understand the thermodynamic processes at work in real world conditions as concrete hydrates and cures, particularly as it relates to concrete foundation walls. The research was conducted in three phases at the Master Builders Test Facility in Cleveland, Ohio, in January 2003.

PHASE 1

Thirty-six different mix designs were cast in cylinders and cured in controlled conditions of 30°F for 28 days. Cylinders were tested for compressive strength at 1, 2, 3, 7, 14 and 28 days in order to develop maturity curves for each mix.

Fig. 1: The refrigerated test chamber at Master Builder's laboratory in Cleveland, OH with all cylinders from Phase I ready for testing. Note the maturity meters in cylinder 1 of each set.

PHASES 2 & 3

Twelve six-foot by eight-foot by eight-inch-thick walls were cast in mid-January in Cleveland, using six common cold weather mix designs. Conditions were very cold, 21°F and falling at the time of casting, and temperatures remained below freezing for 21 days following. Half the panels were poured without cover, the other half with a six-foot blanket covering the top three feet of the wall. All forms and cover were removed the day after casting. Temperature sensors to monitor internal concrete temperatures, cylinders, and cores were used to access curing history, strength, and durability properties.

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Fig. 2: Placement conditions for the full scale walls in Phase 2 included temperatures of 26°F and falling along with active frozen precipitation.

Research Results

Phase 1: All mixes achieved a minimum of 3000 psi in 28 days, despite the 30°F curing conditions.

Phase 2: Despite the extreme weather conditions, all cylinders (cured next to the walls), and cores achieved strengths in excess of 3000 psi; most achieved strengths from 4000 to 6000 psi.

Phase 3: Accelerated freeze-thaw testing and petrographic analysis concluded that all the mixes "...were...freeze-thaw durable."

Conclusions

1. Concrete foundation walls can be cast in extreme cold weather conditions, without protection, using standard winter mixes, without jeopardizing structural integrity of the wall.
2. Concrete in today's world of heated materials, high-early cements, water-reducing admixes, and accelerators is capable of continued strength gain at internal temperatures well below 32°F. Rules and regulations based on ambient temperatures have little or no validity.
3. Maturity curves developed in the lab are remarkable indicators of concrete performance in actual conditions.

Recommendations

1. Contractors should work with their ready-mixed concrete producers to design mixes suitable for cold weather use in their area.
2. Contact the CFA to obtain information for mixes CFA contractors successfully have used, with little or no protection, in extreme conditions down to 0°F.
3. Contact the CFA if you would like to purchase a copy of the CFA's Cold Weather Research Report 2004. This report will be provided free of charge to building and code enforcement officials upon request.

Fig. 3: The remaining wall segments following core sampling to compare to the cylinders taken during placement.

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Applying the Research

There are practical procedures and methods that can be absorbed from this research and applied to your specific projects and markets.

1. The heat of hydration creates a significant lag in internal concrete temperature in relation to ambient temperatures—staying above freezing much longer than the ambient temperature.
2. Cylinders demonstrated strength gains at each break including successive early-age breaks. Recorded strengths from Days 1, 2, 3, 7, 14 and 28 increased at each test for each mix. This information supports a revised theory that cement hydration doesn't stop at 40°F, in fact, strength gain continues well below this temperature.
3. Maturity curves created with prediction software very closely resembled the strengths tested from cylinders and cores in both research phases. This relationship gives further support to the theory that in-place strength can be accurately and adequately determined using simple maturity meters for prediction purposes—making it easier to adjust mix designs to suit individual and regional differences and requirements.
4. Admixtures that reduce water content enhance strength gain at lower temperatures.
5. The amount of "free" water in the mix has a direct relationship to the affects of freezing temperatures. Concrete produced with modern technologies can continue to gain strength, even as the internal temperature approaches a frozen state. Attaining an early-age strength of 500psi prior to the first freeze is sufficient to prevent damage. Ambient temperatures at or below 32°F did not negatively affect the final performance of the concrete. All samples reached or exceeded their designed ultimate strength. Mix designs did cause variable time intervals for gaining target strengths. This provides contractors with information to use with their own mixes to achieve specific performance requirements.
6. In severe cold conditions, although wall strengths may be similar between covered and uncovered walls, covering the concrete for the initial 24-hour period reduces micro-fracturing and therefore improves long-term behavior.
7. It should be no surprise that Type III cement mix designs gain strength faster than Type I cement.
8. Similarly, accelerators such as calcium chloride and non-chloride accelerators speed up the production of heat and therefore produce strengths faster. ■

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ABOUT THE CFA

The Concrete Foundations Association (CFA) was formed in 1975 to serve the interests of poured wall contractors. As an international nonprofit trade association with a diverse membership spread throughout the United States and Canada, maintains a network that permits individuals with needs and interests to seek advice and professional experience while curating forums where contractors exchange ideas and gain insight for technological and practice advancements.