Cold Weather Research Update

Strengths Proved Good, More Research on Long-Term Durability

Figure 1: Research began with laboratory testing at Master Builder's research laboratory in Cleveland, Ohio.

Cold weather is a comin'...scratch that, it's here! Companies throughout the CFA are gearing up with this in mind as they turn the calendar from October to November and recognizing that special considerations are needed for placing concrete during colder weather. However, at an increasing rate, the CFA is hearing that code restrictions imposed by inspectors and officials are becoming overly conservative. One common denominator is that residential construction continues to march ahead at a high rate, and restrictions concerning concrete placement have a definite economic impact on everyone involved in the construction and sale of homes. Success is certainly to be found in learning what steps are needed to lengthen the construction season and how you can keep the projects "flowing" despite freezing conditions.

This is a primary reason why the CFA initiated a cold-weather research project two years ago to study the affects cold temperatures have on the strength gain and durability of concrete in residential walls. While the study is not complete, it is time to begin implementing this research to resolve the issues that have occurred in the past and will certainly come about again this year between contractors, ready-mix producers and building inspectors.

Research began with laboratory testing at Master Builder's research laboratory in Cleveland, OH (Figure 1). Phase I featured a matrix of 36 mix designs (Figure 2) developed based on both "typical" cold-weather mixes and standard mixes used by the Cold-Weather committee members from Ohio to Minnesota. Over 650 cylinders were cast from these 36 mix designs. The raw materials were stabilized to approximately 68°F prior to mixing. Once the cylinders were cast, maturity probes were inserted and then all were immediately placed into temperature controlled rooms of 30°F and 50°F. The committee identified these two ambient temperatures as the most common targets for increased concern coming from inspectors and officials.

A correlation between predicted maturity curves and the actual performance was one principal target for this research. In order to achieve this correlation, temperature probes were inserted through the top of many of the cylinders to record the data until testing (Figure 3). The cylinders cast in the laboratory were kept in the respective temperature-controlled rooms until the time each was broken. This occurred at 1, 2, 3, 7, 14 and 28 days. Breaks were then correlated with the predicted strengths obtained from maturity prediction using the Con-Cure maturity system (www.concure.com).

Phase II in the research program included real world testing of walls (figure 4). The research committee selected six of the best performing, economical mix designs from Phase I to subject to field conditions. Osborne-Medina Concrete in Medina, OH volunteered their plant, materials, and equipment for the site of the full-

Qty of Cement (Sacks per CY)	Cement Type	Admixtures	Curing Temperature
5	I	None	30°F
5.5		1% Calcium	
6	III	2% Calcium	50°F
6.5		1% Calcium with MRWR	
		Non-Chloride Accelerator (NCA)	

Figure 2: A matrix of 36 mix designs was developed.

Figure 3: Cylinders were cast and immediately set into temperature controlled rooms.

scale tests. CFA member Tri-County Excavation of Richfield OH, provided the man-power and conveyer to set and fill the forms provided by Western Forms (www.westernforms.com). Once again, the mixes were produced with 68°F components and placed into the forms on January 10, 2003. The ambient temperature at time of placement was approximately 22°F and dropping. According to recorded weather records for Wayne County Airport, the Medina area did not feel temperatures above freezing for 20 days after the pour. In fact, the records show an unofficial low of –19°F on January 27, 2003.

The research was conducted in a similar fashion to the Phase I procedures. Maturity meters were inserted into the walls to record concrete temperatures, while other data-loggers recorded ambient temperatures. In addition to the walls, cylinders for all mixes were cast and placed in one group under a blanket (figure 5). The volume of concrete in the combined cylinder set equaled the amount of concrete in one of the wall sections. Two walls were cast with each mix (twelve total) and one wall of each received a blanket "cap" that is, a 6-ft. blanket lain over the top 2 to 2+ feet.

The wall forms were stripped at the end of 24 hours (ambient temperature was 20°F). Following form removal, cores were taken from each wall (figure 6). Two locations were cored, one near the top (under the blanket for the "capped" walls) and one near the center of each wall section. These core samples were then broken along with the matching cast cylinders stored under the blanket. This process was repeated to match the laboratory cylinder sets at 1, 2, 3, 7, 14 and 28 days and the results compared to the maturity predictions made with Con-Cure as well as the results from Phase I.

The committee gained a wealth of knowledge from the significant testing. There are additional results that are being sought in order to closely determine what recommendations should be made industry-wide. Phase I resulted in the identification that all 36 mixtures and 44 curves achieved the designed 28-day strengths even when cured under very cold temperatures (near freezing the entire 28 days). There were no failed

Figure 4: Full-scale testing of the walls.

mixes. Phase II provided further conclusive evidence that the design mixtures selected performed well by once again achieving acceptable strengths from cylinder breaks. This was despite the fact that the probes recorded concrete temperatures dropping in some of the leaner sample walls below 32°F in as little as 11 hours.

The committee was also able to substantially prove that maturity prediction "accurately" estimated the strength gain of the mix designs for both laboratory- and field-cured concrete. Perhaps the most significant aspect of the results was that the restrictions for placing concrete in residential foundation wall applications based on ACI 306 appear to be overly restrictive.

Figure 5: Cylinders for all mixes were cast and placed under a blanket.

It should also be noted that under petrographic exam, some field samples showed varying degrees of microfracturing and ice crystal imprints because they were cured well below freezing. While the strengths were good, further study on the long-term durability in a basement wall, using the leaner mixes and under these conditions is being done. Although it is still undetermined whether walls subjected to the frozen state will exhibit higher permeability and lower surface durability, the volume of data supports the empirical evidence that had been gathered over the previous two winters.

What does this information mean to contractors heading into the difficult winter months?

The CFA has offered guidelines for cold-weather concreting over the past few years for purchase. These guidelines, published in 1997 and based on common thought at the time, use target mix designs for specific ambient temperature ranges. Our research shows that ambient temperature only "affects" concrete temperature and that maturity is much more closely dependant on the temperature of the concrete. Basing the practices used and/or the rules and restrictions during cold weather on ambient temperature is without basis.

This testing also concludes that some of the parameters for the prior guidelines are consistent with intelligent concrete practices and must continue to be followed. The components of concrete should be stored and mixed to achieve a minimum delivery temperature of 60°F (with an ideal temperature of 65°F or higher). Additional water in these mixes produces a significantly slower strength gain and much higher risk of freeze damage. The committee verified, during this testing, that the use of blankets, even if only over the tops of the walls extended the time it took the concrete to chill to the ambient conditions. This step is valuable depending on mix design and other conditions, when the ambient temp is near or below freezing.


Figure 6: Cores were taken from each wall.

Let's take a look at some of the key results of this study:

Confirmation of the obvious:

- There are no single, simple answers. This means that multiple mixture designs and protective measures have shown suitability under severe conditions.
- Good mix designs can withstand colder temperatures than lean designs. Variables such as water/cement ratio, admixture choice and delivery temperature are all critical factors.
- A blanket statement that "I can pour any mix I want, any time I want, is just as wrong as a statement saying you can't pour concrete in cold weather.
- Pour any time you want; morning is best when the sun is expected to have an impact, but above all monitor concrete temperatures and maturity.

form better in colder weather than Type I

- Calcium Chloride is still the best "Bang for your Buck" but will not correct problems associated with poor mix design, high W/C ratios, or low concrete temperatures.
- Any given mix is certain to harden at a slower rate in cold weather than it would in warm weather. Make certain your field people are thinking of this as it could create safety concerns (i.e. walls failing during premature backfills, haunches ripping loose because of insufficient tensile strength, etc.).

Among the "news flashes":

- If Cold Weather concerns are critical to a contractor or supplier, he should pick two to four mixes for varying degrees of cold weather exposure and know when to use them. Maturity testing should be used on each localized mix to confirm performance.

Warning to all wall contractors and ready-mix suppliers who read this:

The addition of water on-site beyond what is allowed by the constraints of the mix design will render all of the above factors meaningless and would result in an unsafe condition. The practice of adding extra water to improve workability is quite possibly the main reason building officials shut jobs down in the cold in the first place—because such "wet" mixes have a much higher likelihood of being damaged in freezing weather! It is such a prevalent practice that the sentiment among building inspectors is generally "Better safe than sorry." Moral of the story: Keep the water/cement ratio where it should be – consider using water-reducing admixtures instead of water.

The most important result of this study is that during sub-freezing conditions, contractors should follow a maturity-prediction procedure for validating their individual mix designs that they work out with their ready-mix producer and then monitor the performance of those mixes with measuring devices to ensure that they are maintaining suitable concrete temperatures and achieving suitable maturity. For more information on these results and the availability of a research report contact Jim Baty (jbaty@cfawalls.org) at CFA headquarters (866-CFAWALL) or one of the following Cold-Weather Committee Members.

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Stay Tuned Folks, We're Nott Done!