Casting Residential Foundation Walls in

By Jim Baty, Terry Lavy, and Joe Nasvik

Cold weather concrete technology is founded largely on the premise that concrete freezes early as the temperature declines, and that once frozen, concrete will no longer gain strength. The concrete industry, and particularly the residential wall industry, has seen its share of contractors who “soup” up mixes by adding excessive water onsite to every truckload, making it easier to work with—at least easier on the worker’s back. This misuse of water is one primary reason for misconceptions about cold-weather concreting and is also responsible for code requirements that are far too restrictive, despite evidence for less restrictive measures. As a result, building officials and inspectors routinely shut down foundation projects because they don’t know what is really important.

The Concrete Foundation Association (CFA) feels that it’s important to recognize that there are many variables that affect the performance of concrete in cold temperatures. A substantial mass of concrete in a typical wall is at least somewhat protected from the elements by the formwork and the excavation. These variables and others lead us to

The Concrete Foundation Association embarked on a large cold weather research study involving the casting of 850 cylinders and the 12 wall panels shown here.

PHOTOS: CFA

believe that rules for placing concrete in cold weather should be based on good practice and good concrete more than the weather forecast.

Residential foundation contractors from many regions of the country have appealed to the CFA to conduct a research study to separate fact from fiction. Codes in many areas have become so restrictive during winter that the economy of the residential market has been significantly jeopardized. Restrictive requirements included tenting, full blanketing, curing protection until achieving full design strength, and prohibiting or altering pours in temperatures even as high as 50° F.

The CFA knows that many of these restrictions aren't based on accurate data. In the other extreme, some areas have few, if any, requirements, enabling contractors to develop guidelines based on their experiences, including when and when not to place concrete, or whether to cover it. Contractors often base these decisions on whether they think it's safe for their crews to work at a given temperature. Empirical data collected from contractors in a variety of markets demonstrate success in placing concrete at temperatures that significantly deviate from current code restraints—with good results.

The research project

The interests of residential contractors and the economy of residential concrete during the winter months motivated the CFA to start a research project that would:

- Identify the actual performance of concrete at low temperatures
- Provide information that would help identify good practice, as opposed to excessive measures outlined by some building codes
- Recommend intelligent and common-sense practices in the field.

The goal of the research program was to provide "real world" data about mixes that contractors regularly use, their performance under given conditions, and what economical modifications should be made to improve performances and results. The CFA realizes there is variability in concrete throughout the world. Therefore the research needed to provide contractors with information allowing them to adapt their own mix designs.

Getting started

The research committee formed by the CFA surveyed key industry regions and selected 36 representative mix designs to be tested under laboratory conditions. Concrete mixes would be lab-

Cold Weather

Research conducted by the Concrete Foundation Association sheds new light

oratory tested at 30° F and 50° F ambient conditions. Full-scale field research studies would also be initiated under subfreezing conditions. All mixes were designed with 6% air entrainment and a slump of 6 inches. All mix components were stored at 60° F before batching. The project batched more than 20 cubic yards of concrete for casting and tested more than 850 cylinders and 12 wall samples. For further results, a total of 180 core samples were taken from the walls for testing. The committee decided to use maturity testing (the science of predicting the strength gain of concrete over time given the components of the mixture and the temperature conditions of the placement) because it's proven successful in other concrete industry segments. The plan would be to monitor the samples to track both internal concrete and ambient temperatures. The committee hoped to provide information suitable for any region and climate condition. The final research matrix consisted of 44 maturity curves, produced from the 36 mix designs.

Testing in the laboratory

To develop a thorough understanding of the strength gain for the various mixtures, they cast and placed 6x12-inch cylinders into a refrigerated (50° F) or frozen (30° F) chamber. Cylinders cured at these temperatures were then tested for compressive strength at 1, 2, 3, 7, 14, and 28 days and compared to their maturity curves. This phase consisted of 660 cylinders. The cement content of the mixes was as low as 5-sack (470 pounds) and as high as 6.5-sack (611 pounds), using both Type I and Type III cement. Knowing that admixtures can contribute to strength gain, especially at lower temperatures, the addition of 1% and 2% calcium chloride, midrange water reducers (MRWR), and a nonchloride accelerator (NCR) were also tested.

Once the cylinders were cast, they received thermister probes (temperature-sensitive monitoring devices that are a part of the maturity system) to track internal temperatures coinciding with the ambient temperatures of the chambers. Then the cylinders were immediately placed in the temperature chambers where they remained in their chilled state until their designated testing time. Mix designs are typically based on results from test cylinders placed in "standard moist-curing rooms" set at 70° F and 100% relative humidity. Stored at the refrigerated temperatures, the cylinders in this research project would not have the advantageous curing conditions of standard tests and would more closely resemble the field conditions that many current codes want to restrict. Every attempt was made to provide the full effect of cold weather on the mixes.

Top: Wall panels were cast as part of the second phase of the research study. The research team placed blankets over the top of half the panels and left the others fully exposed to the elements. Different concrete mixes were used for each wall.

Bottom: As a part of the first phase of the study, cylinders were stored in this "cold room" and kept at 30ºF.

Testing in the field

Following the completion of the Phase I laboratory research, the committee moved on to Phase II field research. Full-height formed walls (6 ft wide x 8 ft high x 8 in. thick) were erected under real jobsite conditions. Concrete mixes (representing the most favorable combination of performance and economy) identified in Phase I of the project were used.

All mixes were subjected to uncovered and covered wall conditions with a 6-foot blanket capping the top of the covered walls. Both internal and ambient temperatures were monitored for each wall and a full set of test cylinders was made from each mix. When the wall forms were removed after 24 hours, testing of the cylinders and cores from the walls began. The cores were taken from both covered and uncovered regions, and results were compared to the related cylinder data.

Concrete was placed in the forms on January 10, 2003, with a high ambient temperature recording of 26° F. The forms and blankets were removed on Day 2 (Jan. 11), 24 hours after placement. Temperatures remained below freezing until Jan. 31. Most of this time the temperature was in the low teens to low 20s with a record low temperature for the region of -19° F during this period. The opportunity to record the strength gain of the full-scale walls at such favorable (severe) research temperatures was an added bonus.

The laboratory test mixes that were applied to the field research were as follows:

Mix 3: A 5-sack, Type I mix with 2% calcium only.

Mix 8: A 5.5-sack, Type I mix with 2% calcium only.

Mix 13: A 6-sack, Type I mix with 2% calcium only.

Mix 24: A 5-sack, Type III mix with 1% calcium only.

Mix 29: A 5.5-sack, Type III mix with 1% calcium only.

Mix 34: A 6-sack, Type III mix with 1% calcium only.

Results from the testing

The data resulting from the two-phase project makes it easier to predict strength gains in concrete exposed to cold weather conditions. Here are some insights gained from the research:

1. Ambient temperatures, although they affect the drop in concrete temperature, should not set the restrictive condition. All concrete mixes tested displayed a significant lag in internal 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. The 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 the water content enhance strength gain at lower temperatures.

5. Many references state that concrete must not freeze before it reaches 500 psi. While this may or may not be a valid benchmark for concrete in general, our research indicates it may be less important as a target for residential foundation walls. The amount of "free" water in the mix has a direct relationship to the effect freezing has on concrete. Concrete produced with modern technologies can continue to gain strength even if the internal temperature drops below 32° F before it reaches the 500 psi level. The "frozen state," as predicted by the ambient temperature, did not negatively affect the strength 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. Wall samples in Phase II that were uncovered developed strengths similar to those that were covered for the first 24 hours. Petrographic examination showed improvements in the surface characteristics and reduction in micro-fracturing in the cores taken from the walls that were covered for the 24 hours. Further testing is proceeding to determine if walls left uncovered are more susceptible to freeze/thaw damage over time.

7. Mix designs using Type III cement were shown to gain strength faster than those with Type I cement.

8. The incorporation of calcium chloride at up to 2% as an admixture provides faster strength gain at a low cost. Nonchloride accelerators (NCA) provide the same benefit with less potential for corrosion of steel reinforcement, but at a higher cost.

Recommendations as a result of the research

■ The CFA cautions against the perception that all concrete practices and mixes are appropriate for cold weather.

■ You should work with your local ready-mix producer to design concrete mixes that will perform well based on the expected weather conditions for a placement. The mix designs used in this research provide a sound basis for your own mix development and can be used with confidence.

■ There is no single mix design that works best for cold weather concreting. Results vary as mixes vary but all are predictable, and economy can be kept in mind when you are designing and selecting a mix.

■ Using maturity meters on your projects is a good way to evaluate how your concrete mixes perform.

■ The impact of adding excessive water to concrete under cold weather conditions is significant—the greater the water content, the greater the effect that freezing will have on the concrete.

■ Good common sense and concrete procedures should be observed.

■ Placing concrete early in the day will normally give you an advantage by capitalizing on solar gain to dampen the effect of ambient temperature on internal concrete temperatures.

■ Finally, cold temperatures do cause slower strength gains than normal, so don't remove structural supports from a wall too early. Bracing is always a good idea prior to applying any loads to the walls. ■

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For more information about maturity meters, **circle 1** on the reader service card

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