By Virgil Irick, TCNA Director of Laboratory Services.

Frost Resistance Equals Freeze-Thaw Testing

A Cold Topic With Many Variations

The terms "frost resistance" and "freeze-thaw resistance" are often used interchangeably.

The North American tile industry is very well-acquainted with the ASTM C 1026 standard test method for measuring the resistance of ceramic tile to freeze-thaw cycling. The standard was originally published as C-21 Proposed Test Method P 153 and was issued as C 1026 in 1984. Subsequently, there was an edition in 1987, with re-approval established in 2002. Briefly stated, this method tests 10 tiles that are first saturated, then frozen to 0°F (-18°C) out of water, and thawed by placing them in water between 50-60°F (10-16°C). This cycle is repeated 15 times during which tiles are examined for damage after every five cycles. While this ASTM test has a long history of determining freeze-thaw resistance, it is not an absolute or perfect predictor of a tile or tile installation's survival.

Critics of the method often point out that 15 cycles are far too few. While testing for only 15 cycles may not predict all tiles that will fail in service, any tile that does fail in C 1026 is likely not a good candidate for a freeze-thaw environment where the tile can get wet. This is a wet freezing test; so conversely, tiles that sustain damage in the wet test might perform well if installed in a dry (sheltered) freeze-thaw environment. Additionally, tiles that experience standing water in a free-thaw environment might not perform as well as was indicated in C 1026 testing.

The following section discusses various frost resistance/freeze-thaw concerns and methods, as well as Tile Council of North America's (TCNA) recent work on testing innovations.

What Causes Failure of Ceramic Tile and Other Materials During Freeze-Thaw Cycling?

Porosity is the basic material physical characteristic that contributes to freeze-thaw failure. In ceramic tile, any "open", interconnected porosity accessible by water is usually the guilty culprit. Such

Right: TCNA's Product Performance Testing Laboratory designed and assembled a computer-controlled, multiple-container automated freeze-thaw testing unit. It includes a circulation unit providing temperature-controlled water for thawing test samples.
The unit offers the advantage of being able to perform multiple cycles per day for ASTM freeze-thaw standard tests requiring up to 300 cycles. Photo by Cox Photo Studio.

interconnected porosity can be quantified by measuring water absorption through testing such as ASTM C 373. As the temperature falls, the density of water increases to a maximum at 4°C. As the temperature falls to the freezing point of 0°C (32°F), water expands, and upon converting to ice, experiences a volume expansion of approximately 10 percent. For example, if 10 cups of water are placed in a freezer, the water converts to 11 cups of ice. So, upon freezing, the expansion of water in tile pores can apply significant, internally localized bursting pressure to the body. The pressure created by ice formation can burst 12-inch thick cast iron pipe.

Repeated cycling near water's freezing temperature can inflict cumulative damage in either glazed or unglazed tiles. However, it should be noted that porosity alone is not a reliable predictor of whether a ceramic tile will fail freeze-thaw testing. There are many porous materials that are freeze-thaw resistant. The key to their survival is the size of the pores making up the porosity and whether water can either drain from the pores prior to freezing or expand into unfilled space within pores during freezing. However, even frost resistant porous materials, when exposed to standing water subject to freezing, can experience freeze-thaw damage.

It is important to understand that all floor installations should have movement joints, and that the use of a crack isolation membrane does not replace or eliminate the need for movement joints.

Are There Hard and Fast Guidelines Limiting Water Absorption/Porosity of Ceramic Tile For Freeze-Thaw Environments?

An often-cited but substantially incorrect rule of thumb is that tiles with a water absorption greater than 3% are not generally suited for outdoor freeze-thaw conditions. While true for some tiles, there are many tiles, and especially extruded paver tiles, with greater than 3% water absorption, suitable for exterior use. Some paver tile manufacturers are now testing products hundreds or even thousands of cycles.

What Other Ceramic Products Are Commonly Evaluated For Freeze-Thaw Behavior?

Other than tile, the two ceramic products most widely evaluated for freeze-thaw behavior by ASTM and other testing standards are brick and concrete. There are numerous standards for concrete and associated aggregates. In the brick industry, there are testing standards for conventional unit sizes (ASTM C 67) and for thin veneer brick (ASTM C 1088). Additionally, ASTM C 666 covers a rapidly growing construction product comprised of thin veneer brick cast into the face of reinforced concrete. For both conventional and thin veneer brick, 50 cycles of freezing and thawing are required. For brick veneered concrete panels, 300 cycles are required. It should be noted that brick can exhibit water absorption values up to 20% and still be rated for exterior use. The causes of freeze-thaw failures previously mentioned apply to brick as well as tile.

Concrete will continue to shrink long after it is first cast, and it is possible for the concrete to crack due to shrinkage while it is curing.

How Do the Three Freeze-Thaw Test Methods For Tile Differ?

In addition to the C 1026 test already discussed, there are two others commonly used overseas for measuring tile:

European Standard EN 202: The tile is vacuum saturated with water and chilled "dry" to -5°C (-23°F), then rapidly heated by water to 5°C (41°F). The tiles must remain above 5°C for 15 minutes and survive 50 cycles.

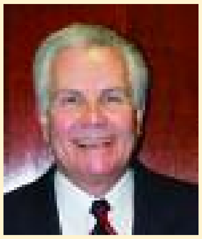
International Standard ISO 10545-12: The freezing procedure in this test is the same as for EN 202, but the tiles are exposed to 100 freeze-thaw cycles.

ASTM C 1026: In this test, the tiles are saturated and then frozen "dry" to -18°C (0°F) then rapidly heated to 10-16°C (50-60°F) by placing them submerged in water for 30 minutes. Tiles are exposed to 15 cycles.

What is TCNA'S Product Performance Testing Laboratory Doing to Broaden Its Freeze-Thaw Testing Capabilities and to Examine Possible Improvements in Methods?

In the past year, TCNA's laboratory staff designed and built a computer-controlled, automated freeze-thaw test system. This system is capable of independently controlling freeze-thaw cycling in up to ten sample containers. Container size was selected so that large samples, such as thin brick set in concrete, can be placed horizontally. Tile can be coin-stacked with spacers or edge-stacked to maximize the number of samples tested at a time. A water temperature conditioning and pumping unit is included in the hardware so that the temperature of the water used for thawing can be selected with water recirculated through each tank. Clear advantages of this computer-controlled unit include multiple-tank independent operation, operator-free 24/7 operation, and multiple cycles per day. For example, 300 cycles can be achieved in slightly more than one month. **TILE**

About the Author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