Portland cement concrete with commercially available admixtures was placed in Wisconsin and New Hampshire during subfreezing temperatures without heated enclosures, producing savings of 20 to 90 percent in materials and placement costs. The technique could extend the cold-weather construction season by as much as four months in many parts of the United States.

Portland cement concrete generally cannot be placed during subfreezing weather without thermal protection. Recent research by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), however, has demonstrated that commercial admixtures can protect concrete from freezing. The admixtures can extend the concrete construction season into the winter.

Problem
Cold-weather construction practice requires that concrete be delivered warm to the construction site, that the substrate be thawed, and that the concrete be kept warm while curing. At temperatures near 40°F, insulation usually suffices to allow the placement of concrete. When the temperature drops below 40°F, however, heated enclosures, insulation blankets, and other thermal protection become necessary—but are not always practical. As a result, concrete pavements are seldom constructed when air temperatures approach 40°F.

Solution
In a pooled-fund project for the Federal Highway Administration, CRREL developed an antifreeze concrete for highway paving at subfreezing temperatures. The project required off-the-shelf admixtures and application at 23°F or lower, with adequate strength, constructability, and economy. CRREL evaluated combinations of commercially available admixtures to depress the freezing point of water and to accelerate the hydration rate of cement. Previous research showed that no single admixture in recommended amounts could provide enough freeze protection to meet the low-temperature requirement.

Current practices limit the amount of each admixture to concrete. No limits apply, however, to the number of admixtures in a single batch, and concrete with more than one admixture is not uncommon. The literature reports five or more admixtures but does not indicate if the purpose was to prevent the concrete from freezing during application.

CRREL researchers produced candidate formulations by combining several commercial admixtures that met standards, all within the recommended dosages. The formulations were evaluated under controlled laboratory conditions, to identify the admixture combinations that could accelerate curing, ensure workability, provide adequate freezing-point depression, and not harm the freeze–thaw durability.

The laboratory tests indicated an appreciable strength gain for the candidate formulations at 23°F;
with no adverse effects on durability. The formulations were then evaluated in field tests.

The demonstrations of the antifreeze concrete technology took place at five locations in Wisconsin and New Hampshire. The concrete was evaluated for

- Batch mixing,
- Transportability,
- Ease of placement,
- Cost and time,
- Compatibility with common practice,
- Finishability, and
- Equipment and labor issues.

In one project in Rhinelander, Wisconsin, in February 2002, a section of pavement 10 feet wide by 22 feet long by 10 inches deep was removed and replaced with antifreeze concrete. The air temperature was 14°F at the start of work, rose to approximately 32°F during placement of the concrete, and then dipped to 10°F in the evening.

Removal of the pavement and replacement with fresh concrete were completed within 3 hours. The freshly placed concrete was covered with a layer of plastic to minimize moisture loss, and an insulation blanket was laid over the plastic to speed up the strength development; the insulation blanket, however, was not necessary for freeze protection.

The pavement section was opened to traffic 48 hours later. Except for the corrosion-inhibiting and accelerating admixtures, the antifreeze concrete contained the same materials in the same proportions as the normal-weather concrete, including the same measures of air-entraining and water-reducing admixtures. Two years after construction, the antifreeze demonstration sections show no signs of distress.

**Benefits**

Antifreeze concrete made with commercial admixtures allows unprotected placement and normal curing at external temperatures as low as 23°F. Antifreeze admixtures increase the concrete material cost but reduce the placement costs by eliminating the need for heat, shelter, and extra labor.

On the Rhinelander project, the antifreeze technology reduced the cost by nearly 20 percent compared with the cost of using a heated enclosure. The savings on other projects were greater. For example, one New Hampshire project realized a 90 percent reduction in materials and placement costs with antifreeze concrete instead of regular concrete under conventional heated enclosures. After surface preparation, the antifreeze section on this project was placed and finished within a few hours; erecting and dismantling the shelter for an identical control section would have required several days.

Use of antifreeze concrete also extends the construction season by 60 to 120 days (Figure 1) and ensures that the concrete can be placed safely on frozen substrates, that it will develop adequate strength despite exposure to low temperatures, and that it will exhibit adequate freeze–thaw durability.

Extending roadway construction into colder seasons, when traffic volume is lower, offers the following benefits:

- Reducing the adverse impact of construction on the public;
- Decreasing the number of work zone accidents; and
- Improving the utilization of construction equipment and labor by extending the seasonal limits of construction work.

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Suggestions for “Research Pays Off” topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).