

## Liquid Nitrogen for Concrete Cooling

This process may be the best way to control the temperature of your mass concrete placement

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BY WILLIAM BEAVER

**T**he use of liquid nitrogen (LN) to cool concrete began more than 20 years ago, but only sporadically and with a great deal of skepticism. Until recently, safety concerns and lack of understanding slowed any widespread use of LN by the concrete industry. This article describes the successful use of LN to cool concrete by the Texas Department of Transportation (TxDOT) for the State Highway 45 Turnpike Project in central Texas.

### LN

As the name implies, LN is simply nitrogen gas converted to a liquid form. At air separation plants, fractional distillation converts nitrogen to a liquid, a process that contracts and expands the gas until it converts to a liquid at a temperature of  $-326^{\circ}\text{F}$  ( $-200^{\circ}\text{C}$ ). Once converted from a gas, the liquid is 99.95% pure

nitrogen and inert. Because it doesn't react negatively with other gases or chemicals, it has many common uses.

As a means of cooling concrete, nothing matches LN, especially when it comes to large placements in hot climates. "The beauty of LN is that it produces a much lower concrete temperature than chilled water or ice. And because LN is inert, it does nothing negative to the concrete; it just cools it. In fact, it's so inert it's often used to blanket oils and other potentially volatile materials," said Steve Dziak, South Central Region Manager for Air-Liquide America, one of the world's largest producers of LN. "Depending on state specifications, the outdoor temperature, and the size of the concrete placement, LN can be less expensive than ice or chilled water. And unlike ice, it cools concrete more uniformly, which creates a more consistent slump."

## LN'S APPEAL IN THE SOUTH

In the South, inordinately high summer temperatures can make it difficult to cool concrete uniformly. In Texas, for example, the daytime temperature routinely exceeds 100 °F (40 °C), and often by a wide margin. Placing concrete at night helps somewhat, but not a great deal.

Jobe Concrete's El Paso division introduced LN cooling in Texas about 9 years ago. The cooling process proved so successful in west Texas that TxDOT Austin District began using LN in 2003 on the State Highway 45 section of the \$4 billion Central Texas Turnpike Project. It is the first time LN has been used in central Texas.

For its inaugural test run in August 2003, Transit Mix Concrete Co. of Austin batched 8 yd<sup>3</sup> (6 m<sup>3</sup>) of concrete at a temperature of 95 °F (35 °C). After LN was injected for 8 min, the concrete temperature dropped 20 °F (11 °C). After an additional 3 min of mixing, it was delivered to the job site and placed in a drilled shaft. The resulting concrete temperature at the job site was 78 °F (26 °C), 15 min after batching. Texas Turnpike Authority (TTA) construction managers were so pleased that they intend to use LN exclusively on the remainder of the project, according to Joe Dan Johnson, Regional Quality Control Manager for Transit Mix.

For the turnpike project, Transit Mix is using an on-site, drive-through bay with an LN tank that it leases. While concrete is being batched, technicians insert a 6-ft-long (2 m) LN lance into the concrete truck and spray the mixture with LN. How long the concrete is sprayed depends on how much concrete is being batched, the distance it must be transported, and the temperature specifications it must meet. In Texas, concrete placed for

bridge decks cannot exceed 85 °F (30 °C). For mass placements, the temperature specification is 75 °F (24 °C).

"On mass concrete placements, getting the temperature down to 75 °F with ice, especially if you're in Texas, is difficult and expensive," said Ray Loya, Plant Production Manager for Jobe Concrete. "On some jobs, it's cheaper to use liquid nitrogen, and you're more likely to get a more consistent slump."

Slump consistency can be unpredictable when ice or chilled water is used to cool concrete. Until fairly recently, however, ice water was practically the only way concrete was cooled, often with marginal results. LN allows the use of the correct amount of mixing water in the concrete batching operation, which provides uniform mixing of ingredients. Ice, which replaces mixing water, can cause poor mixing of ingredients. With chilled water, it isn't unusual to see a 35 °F (19 °C) difference between the internal temperature of the hardened concrete and the temperature on the concrete surface.

## DIFFICULT TO COOL

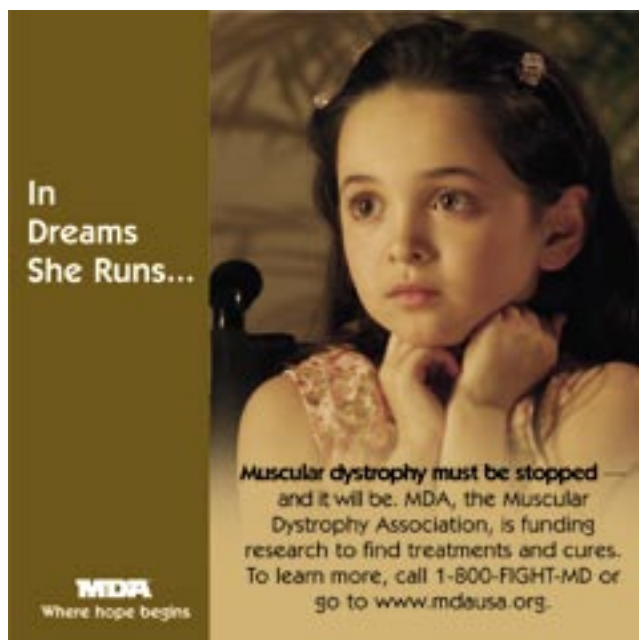
Whatever process is used, cooling concrete is never an easy process. Aggregate, which comprises 60 to 80% of the concrete volume, absorbs heat easily. The other key ingredient, cement, can come out of the kiln as clinker at 1000 °F (540 °C). After it's ground and stored in silos, it cools considerably, but it still can have an ambient temperature of 130 °F (55 °C) or higher when shipped to the batching plant. To reduce the rate of concrete slump loss and later temperature increase due to hydration, producers replace some of the cement with fly ash. Retarding admixtures can also help to produce a more uniform setting time and offset the effects of hot weather on water demand.<sup>1</sup>

Until recently, construction managers had a choice of chilled water or crushed ice to cool concrete during placement. When the choice was chilled water, chiller units had to be erected fairly close to the job site. Expensive to purchase, they must turn out a lot of cold water very quickly to be effective.

Chilled mixing water doesn't stay cold very long when mixed with 90 to 100 °F (32 to 38 °C) aggregate, especially on a summer day when the air temperature is 90 °F (32 °C) or higher.

More often, ice is used to bring down the concrete's temperature. Like chilled water, a great deal of ice must be used to be effective. Because ice machines are so expensive, most concrete companies buy ice from vendors and transport it to their batching plants in refrigerated trucks.

Less labor-intensive, LN can offer a more inexpensive way to lower temperatures. Using LN, it would cost about \$75 to lower the temperature of a 10 yd<sup>3</sup> (8 m<sup>3</sup>) truckload of ready mixed concrete from 95 to 75 °F (35 to 24 °C).



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To lower the temperature from 95 to 85 °F (35 to 29 °C) would cost about \$40. Other costs for capital, installation, and rental on storage vessels need to be included. The total cost, however, can be less than cooling with chilled water or bags of ice.

Recently, Jobe Concrete used LN on three concrete placements. Although LN can be employed at the batching plant before delivering the concrete, Jobe ordinarily uses a portable LN tank that allows the cooling process to take place at the construction site, saving time.

“When LN comes out of the lance it’s about -320 °F,” Loya explained. “If the hot concrete is 85 to 93 °F, you can cool it down to 60 °F in 5 or 6 minutes with LN. But you can’t waste a lot of time in delivery because the State gives us only 90 minutes per truck when the concrete specification is 75 °F.”

Jobe’s portable tank is mounted on a low-boy trailer. Constructed of conventional steel, the pressurized tank has pop-off valves and copper tubing. The LN lance, connected to the tubing, is inserted into the mixer and sprays LN on the top of the mixing concrete (Fig. 1). The lance does not penetrate the concrete.

To keep the process as economical as possible, Jobe orders only the amount of LN it needs for a project. Unused LN not only wastes money, but over time, it will boil off and vent into the atmosphere. For companies wanting to install a permanent LN cooling system at their plant, the cost is about \$40,000. Although relatively inexpensive, permanent systems are still somewhat rare because few companies use LN cooling on a regular basis. The third option—a drive-through facility like the one used on the Central Texas Turnpike Project—typically costs about \$30,000, Dziak said.

### FURTHER RESEARCH NEEDED

Practically everyone who has used LN to cool concrete extols its many virtues, but there has not been a great deal of testing. What is known is that if LN is not used properly and controlled in the correct manner, it can crack the drum in a concrete truck. That’s why it is important for practitioners of LN cooling to thoroughly understand how the system works, how the liquid is controlled, and the safety aspects of using cryogenic liquid. They must also understand how to use proper ratios to reach the desired concrete temperature.

Most of all, concrete professionals must understand what LN can do to a human being. So far no Texas construction worker has been badly injured, but all agree that safety rules need to be strictly enforced.

“For those of us in the construction trades, LN appears



**Fig. 1: The LN lance is connected to tubing and is inserted into the mixer, spraying LN on the top of the mixing concrete**

to be a very promising alternative in the concrete cooling process,” said TxDOT Bridge Engineer Ralph Browne. “But there is a lot more we need to know about how liquid nitrogen affects cement hydration products, concrete set, and concrete production equipment as well.”

“At the same time, there are safety issues that need to be addressed more fully,” Browne continued. “The development of standard implementation plans for different LN mishap scenarios should be developed. What should you do if a pipe bursts or a lance slips out? TxDOT will be conducting research on this topic via the 5111 research project. A broader understanding of the safety issues will be addressed within this research.”

### References

1. ACI Committee 305, “Hot Weather Concreting (ACI 305R-99),” American Concrete Institute, Farmington Hills, MI, 20 pp.

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