PCA Portland Cement Association

CONCRETE TECHNOLOGY Today

Conductive Concrete for Bridge Deck Deicing

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Figure 1 (above): Two 89 x 89 x 6-mm (3½ x 3½ x ¼-in.) angle irons spaced about 1 m (3.5 ft) apart were embedded in each slab for electrodes in a back-to-back fashion. (IMG14730)

Figure 2 (below): Deicing system in operation in February 2004. (IMG14728)

CT041 — March 2004
Vol. 25, No. 1

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Concrete Technology Today is now available on the Internet at www.concretetechnologytoday.org

Heated deck of Roca Spur Bridge in Nebraska is the world's first implementation using conductive concrete for deicing

Roca Spur Bridge is a 46-m (150-ft) long and 11-m (36-ft) wide, three-span highway bridge over the Salt Creek at Roca, located on Nebraska Highway 77 South about 24 km (15 miles) south of Lincoln. A railroad crossing is located immediately following the end of the bridge, making it a prime candidate for electrical deicing application. The Roca Bridge project began in December 2001, and construction was completed in November 2002. The bridge deck has a 36-m (117-ft) by 8.5-m (28-ft) by 100-mm (4-in.) conductive concrete inlay, which is instrumented with thermocouples to provide data for deicing monitoring during winter storms.

Mix Design

Conductive concrete contains a certain amount of electrically conductive components in the regular concrete matrix to attain stable and relatively high electrical conductivity. The mix design used in this project contained steel fibers and carbon products for conductive materials. Steel fibers of variable lengths amounted to 1.5% and the carbon products of different particle sizes amounted to 25% per volume of the conductive concrete. Crushed limestone of 13-mm (0.5-in.) maximum size and Nebraska 47B fine aggregate were also used in the mix. Due to its electrical resistance and impedance, a thin conductive concrete overlay can generate

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enough heat to prevent ice formation on a bridge deck when connected to a power source.

Project Significance

It is expected that this project will demonstrate that conductive concrete technology has national and international importance. Statistics indicate that 10% to 15% of all roadway accidents are directly related to weather conditions. This percentage alone represents thousands of human injuries and deaths and millions of dollars in property damage annually. Ice accumulation on paved surfaces is not merely a concern for motorists; ice on pedestrian walkways accounts for numerous slip and fall injuries. The payoff potential for this project is tremendous: it could eliminate icy bridge roadways and save lives. This revolutionary deicing technology is applicable to accident-prone areas such as bridge overpasses, exit ramps, airport runways, street intersections, sidewalks, and driveways.

Construction Sequence

A 100-mm (4-in.) thick inlay of conductive concrete was cast on top of a 256-mm (10.5-in.) thick regular reinforced concrete deck. The inlay consists of 52 individual 1.2-m x 4.1-m (4-ft x 14-ft) conductive concrete slabs. In each slab, two angle irons were embedded for electrodes (Figure 1). Coupling nuts were welded to one end of the angle irons for making an electrical connection. A thermocouple was installed at the center of each slab at about 13 mm (0.5 in.) below the surface to measure the slab temperature. The power cords and thermocouple wiring for each slab were secured in two PVC conduits and are accessible from junction boxes along the centerline of the bridge deck.

The conductive concrete inlay was cast after the regular bridge deck had been cured for 30 days. The westbound lane was placed first. After hardening, the conductive concrete inlay was saw cut to a 100-mm (4-in.) depth along the perimeters of the individual slabs, and the gaps were filled with polyurethane sealant. There was a 150-mm (6-in.) gap along the centerline of the bridge to allow power cord connections with the coupling nuts of the angle irons. The gap was then filled with a non shrink, high-strength grout.

Integration of Power Supply, Sensors, and Control Circuit

A three-phase, 600 A and 220 V AC power source is available from a power line nearby. In a control room a microprocessor monitors and controls the deicing operation of the 52 slabs. The system includes four main elements: (1) a temperature-sensing unit, (2) a power-switching unit, (3) a current-monitoring unit, and (4) an operator-interface unit. The temperature-sensing unit takes and records the thermocouple readings of the slabs every 15 minutes. A slab's power will be turned on by the controller if the temperature of the slab is below 4.5°C (40°F) and turned off if the temperature is above 12.8°C (55°F). The power-switching unit controls power relays to perform the desired on/off function. To ensure safety, a current-monitoring unit limits the current going through a slab to a user-specified amount. The operator-interface unit allows a user to connect to the controller with a PC or laptop via a phone modem. The operator interface displays all temperature and electrical current readings of every slab in real time. A user also has the option of using a PC or laptop to download controller-stored data into a spreadsheet.

Deicing Operation

The deicing controller system was completed in March 2003 and was tested successfully under snow storms in January and February 2004 (Figure 2). The system was activated in 2003 for an early April storm with less than 6 mm (1/4 in.) of sleet. The slush on the bridge deck was melted during the storm period. Temperature distribution was uniform across the bridge. The controller system kept the slab temperature about 9°C (16°F) above the ambient temperature.

The 52 slabs were energized in an alternating fashion to avoid a power surge. Groups of two slabs were started up in turn at 3-minute intervals and energized at 208 V for 30 minutes. This alternating form of energizing the slabs was followed throughout the storm. The maximum current recorded varied between 7 and 10 amps, with an average of 8. Peak power density delivered to the slabs varied between 360 and 560 W/m^2 (33 to 52 W/ft^2) with an average of 452 W/m^2 (42 W/ft^2). Energy consumed by the conductive slabs during the three-day period varied from 47 to 70 kW-hr, with an average of 58 kW-hr per slab. Total energy consumption was about 3,000 kW-hr.

The conductive concrete bridge deck will continue to be studied for the next several winters to evaluate the effect of electrical deicing and compare it to alternatives. This promising new technology should prove to be a valuable tool in the fight against icy conditions on roadways.

Reference

More information on the conductive concrete bridge deck project can be found at: *www.conductive-concrete.unomaha.edu*.