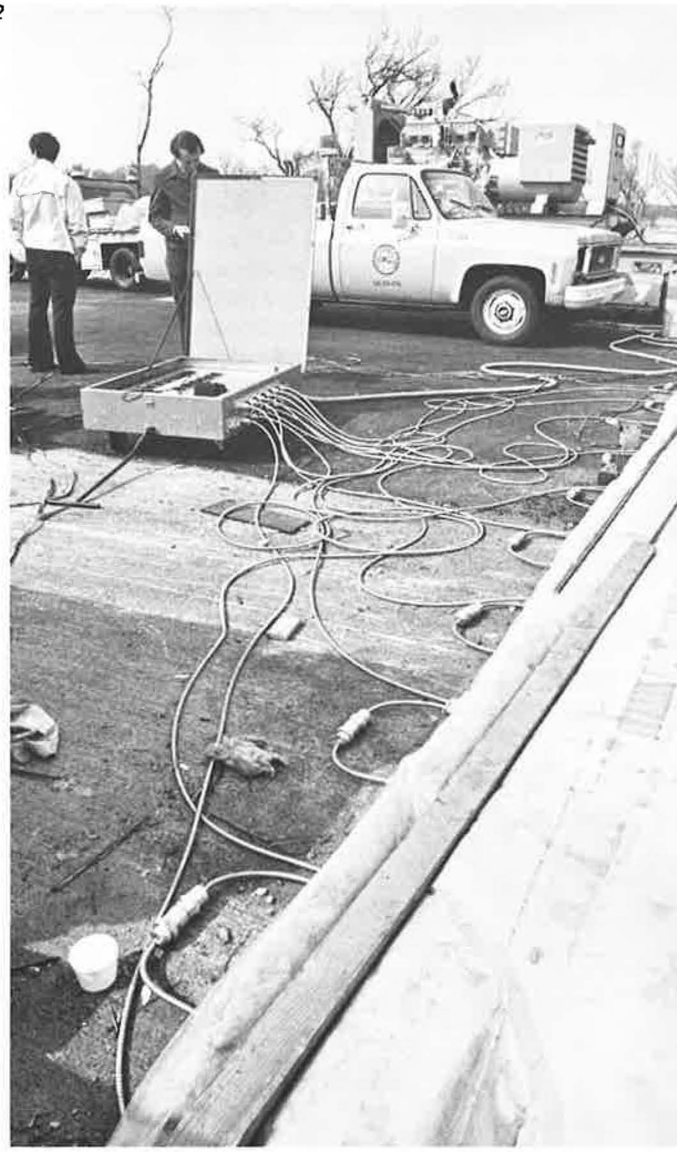
Electric Blankets and Wax Beads Combined In Novel Construction



The Oklahoma Department of Highways has combined electric blankets, wax beads, and concrete in a first of a kind experiment that may be a trailblazer for other states. In a cooperative research project with the Federal Highway Administration and the Monsanto Research Corporation, Oklahoma highway crews tested a new process to make the road surface watertight on a bridge over the North Canadian River east of Shawnee on Okla-3.

One end-span (22.5 by 14.9 m by 24 cm or 75 by 49.75 ft by 9.5 in.) of the 255.8-m (852.50-ft) bridge contains the wax bead and concrete mixture. The remainder of the deck will receive a membrane waterproofing.

Highway director R. A. Ward said this project may provide a solution to the deterioration of bridge decks, a problem that has plagued highway departments nationwide.

The process involves mixing small wax beads with fresh concrete as the bridge deck is poured. After the concrete has cured the wax is melted. In this experiment the heat came from huge electric blankets, which were

1 Engineer Gary Hamacher of the Oklahoma Department of Highways checks connection on electric blanket used to melt the tiny wax beads. The insulation seen in the background helped to hold the heat close to the deck.

2 The wax bead connection—electric blanket, control box, and a huge 480-V generator all combine to melt the wax in a 341.4-m² area on Okla-3 bridge over the North Canadian River.

An electric thermometer, attached by thermocouples to the treated portion of the deck, was used to record temperature readings during the heating process.

provided by the Federal Highway Administration. Electricity for the experiment came from a rented 480-V diesel-powered generator with an output capacity of 200 kW.

The wax beads were developed by Monsanto Research Corporation and produced by Interpace Corporation in Ione, California, at a cost of \$1.08/kg (\$0.49/lb) for the 6.8 Mg (7.5 tons) ordered. They consist of 25 percent ±5 percent montan wax and 75 percent ±5 percent paraffin and are 20 to 80 mesh spherical particles. Montan wax is a natural occurring, polar mineral wax, which is found in lignite formations. Paraffin, of course, is a waxy, crystalline, hydrocarbon material, which is obtained primarily from distillates of petroleum. The paraffin used has a melt point of 65°C ± 1.1°C (149°F ± 2°F). This blend of wax beads has an approximate specific gravity of 0.90 to 0.95 and a unit weight of 897 to 945 kg/m^3 (56.0 to 59.0 lb/ft^3).

The concrete mix is a standard AASHTO, AA non-air-entrained mix and only differed from the standard mix by the replacement of 0.06 m^3 (2 ft^3) of sand with an equal volume of wax beads (3 percent by weight of concrete). Average compressive strength of cylinders cured 3 to 28 days was 34.3 MPa (4,970 lb/in.^{2}). The strength of non-air-entrained concrete with the wax impregnated is equal to or greater than 6 percent air-entrained concrete. Experience shows that the "unintentional" air content of a non-air-entrained sealed mix with No. 7 aggregates may be as high as 3 to 4 percent.

After the concrete has cured, heat is applied, and the wax beads melt and flow into the capillaries and bleed channels of the concrete. When the heat is removed, the wax solidifies in the pores and capillaries. The penetration of water and chloride is thereby blocked in so that the continuous capillary system in the concrete has been transformed into a discontinuous one.

The electric blankets used to melt the wax are prototypes built especially for experimentation with the wax bead process. This heating system consisted of 22 blankets, each 38.1 cm (15 in.) wide and 14.6 m (48.75 ft) long. The blankets were constructed of metal heating elements and electrical insulating material and have an electrically continuous stainless steel outer sheath on both sides, including stainless steel covers over the hinges, which are placed every 38.1 cm (15 in.). The stainless steel sheathing on the underside of the blankets was blacked to maximize radiant heat transfer. The continuous stainless steel sheathing is used as a positive grounding system. The blankets have a constant power of 1.1 kW/m^2 (100 W/ft^2) at 21°C (70°F) in all areas, except one 38.1-cm (15-in.) long panel on each end. These end panels are variable power sections and are used to prevent stress cracks created by the heat. Power in these sections varies in an approximately linear manner from 1.1 kW/m^2 (100 W/ft^2) at 21°C (70°F) at the point where they contact the constant power section to 0 power at the opposite end. Average power in these sections is 355 W/m^2 (33 W/ft^2) at 21°C (70°F). The total effective full power heating area is 116.9 m^2 (1,258 ft^2). The power to the blankets is critical, for the power is proportional to the square of the voltage; thus, a loss of 20 V (from 480 to 460 V) is a loss in power of 8.2 percent.

The blankets are designed to heat at a slow, uniform rate and not to exceed the maximum allowable surface temperature of 160°C (320°F). They were covered with 15.2 cm (6 in.) of unfaced building insulation to allow any moisture in the deck to escape. The blankets were designed such that 4 heating moves were required to heat the end span. The first heat section required the longest time because of high moisture content within the deck. The heating times were a function of not only how much moisture was present but how soon the voltage was increased. The voltage ranged from 480 to 573 V. Heat times for the end span were as follows: heat section 1, 13 hours, 40 minutes; heat section 2, 12 hours, 47 minutes; heat section 3, 10 hours, 50 minutes; and heat section 4, 10 hours. These times were required to allow heat penetration to a depth of 5 cm (2 in.) at a temperature of 85°C (185°F).

Several problems were encountered in this first full-scale heating process. The major problem was the weather. It rained and drizzled for 2 days before the heating process began, and thus there was a high moisture content within the deck. This was believed to be the reason for a small amount of free standing wax under the blankets after the first heating process. Another weather problem was temperature. Since the heating process continued 24 hours a day until completion, the low night temperatures, dropping to nearly 0°C (below 40°F), caused a great amount of heat loss. Also, wind created difficulties in keeping the insulation on the blankets and extreme difficulties in moving them.

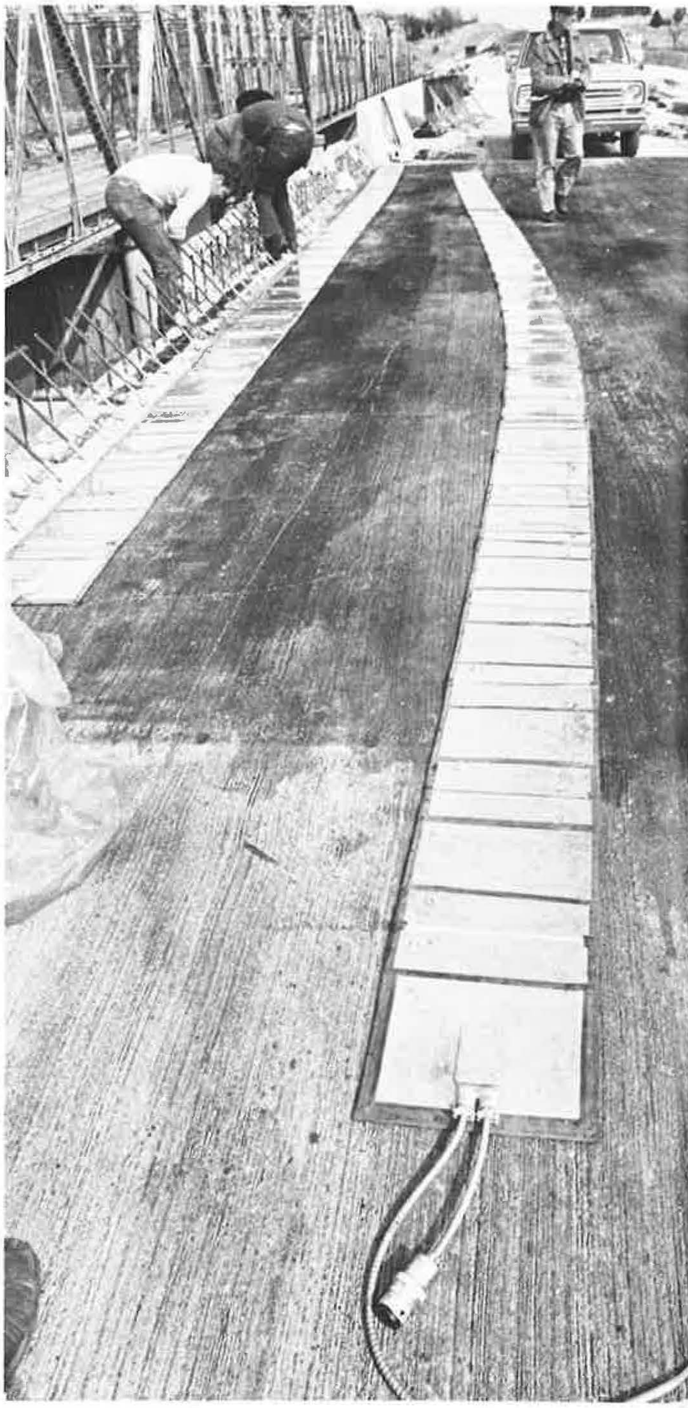
In addition, the contractor poured the parapet walls on the shoulder slabs 2 days before the heating process began. These walls extended out over the deck approximately 30 cm (1 ft) and created an area that could not be heated by the blankets. Because the walls were tied into the deck, small stress cracks were created in them when the deck cooled and contracted. Also, some minor D-cracking occurred at the interface of the shoulder slabs, which were fixed in place, and the deck because of the great amount of compression created when the deck was heated.

Minor problems were encountered because the electrical system monitoring the thermocouples did not trigger properly. However, there were sufficient thermocouples in the deck to detect any faulty ones.

Evaluation

Core samples from the treated area have been sent to the Federal Highway Administration laboratories in Washington, D.C., for electron microscope scanning, which will indicate whether a proper distribution of the wax was achieved. The scanning will also reveal possible stress cracking brought about by the heat from the blankets.

Water penetration tests will be made periodically after the bridge has been opened to traffic. Although it is still too early to rate the wax-bead process as an alternative to other more expensive means of bridge deck protection, engineers at the Oklahoma Department of Highways will keep a close watch on this experimental test span.



The electric blankets were made of stainless steel, contained a standard resistant type of heating element, and measured 38 cm wide and 14.6 m long. The old narrow truss bridge, which is being replaced by the present construction, is seen in the upper left corner.