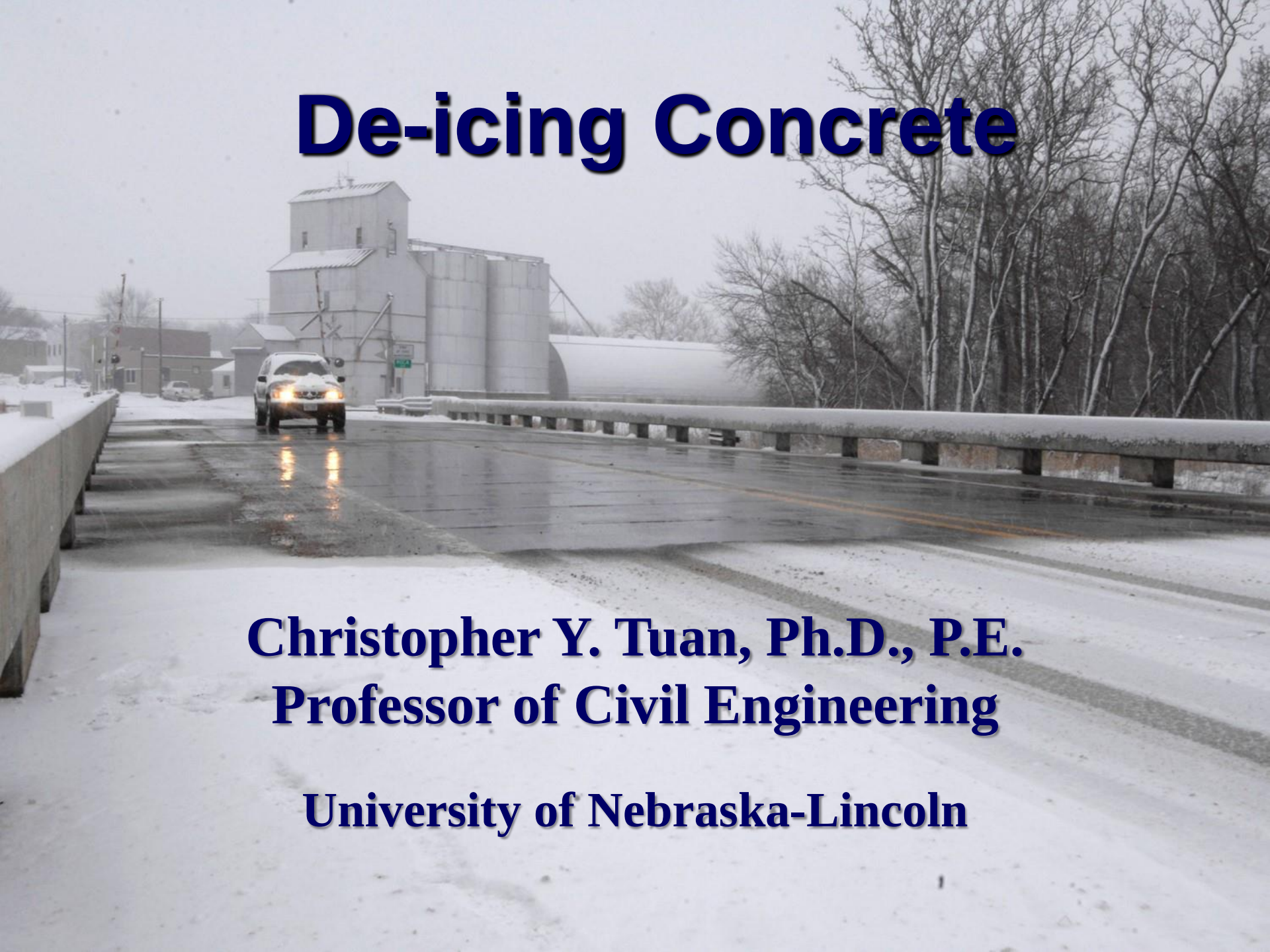
De-icing Concrete



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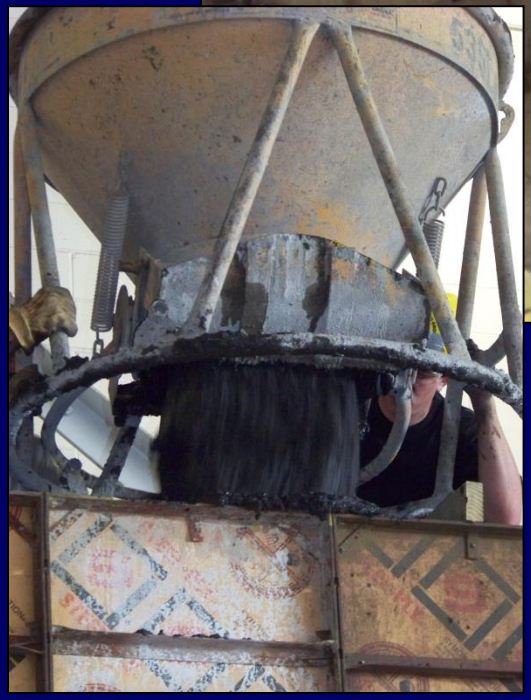
What is Conductive Concrete?

"A concrete mixture containing a certain amount of electrically conductive materials, designed to enable conduction of electricity."

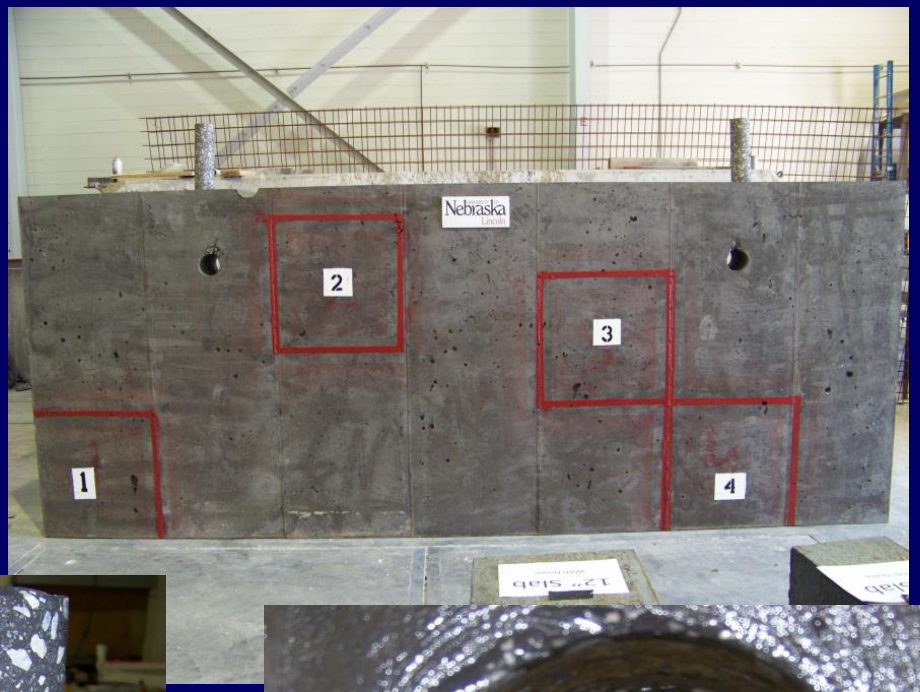
Steel fibers

Carbon particles

Workability and Finishability



Works just like normal concrete



High Strength of Conductive Concrete

- Compressive Strength (ASTM C39)

  7-day: 5,000 psi 14-day: 5,850 psi 21-day: 6,340 psi

  28-day: 6,600 psi
- Bending Strength (ASTM C78)

  28-day Modulus of rupture = 1,100 psi

Applications

* Pavement deicing
* Electromagnetic wave shielding
* Radiant heating
* Anti-static flooring/grounding
* Cathodic rebar protection
* Structural health monitoring

Active Applications

Bridges and Roadways deicing

Radiant Heating Tiles

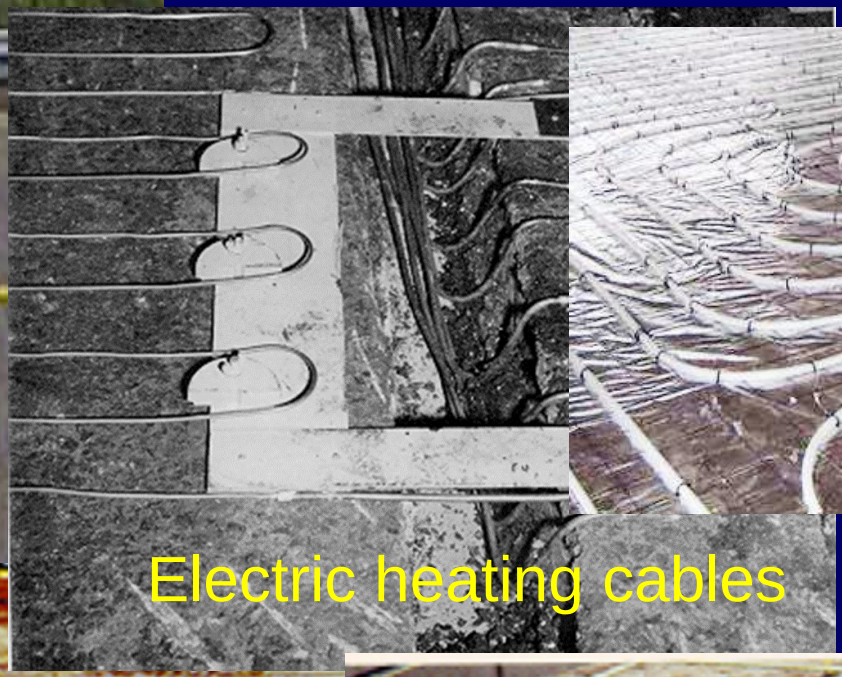
Passive Applications

Electromagnetic Pulse Shielding

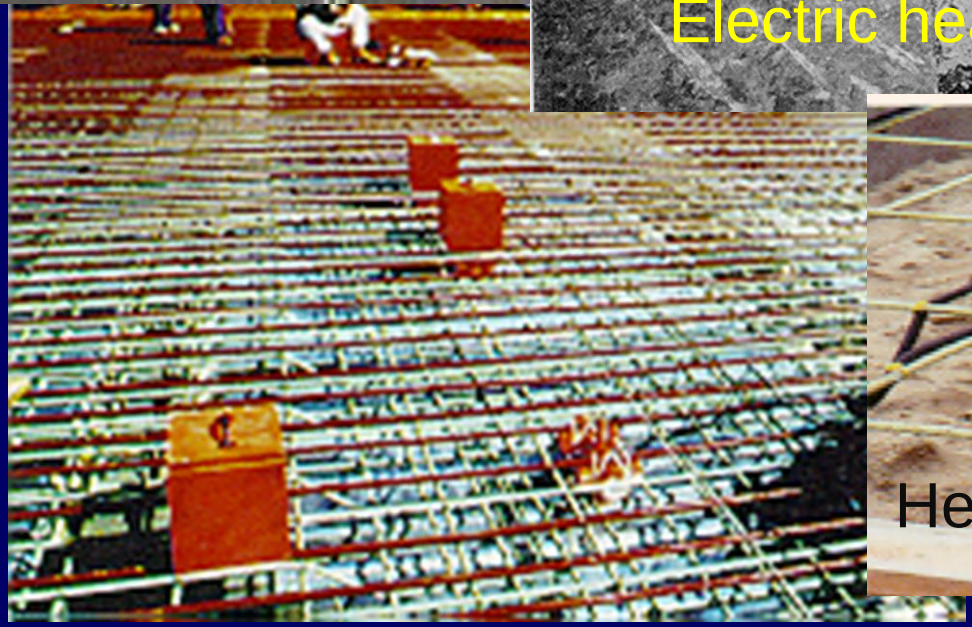
Naval Air Station
VEMPS Grounding Plane
Pax River, MD

Existing Deicing Technologies

Spray system

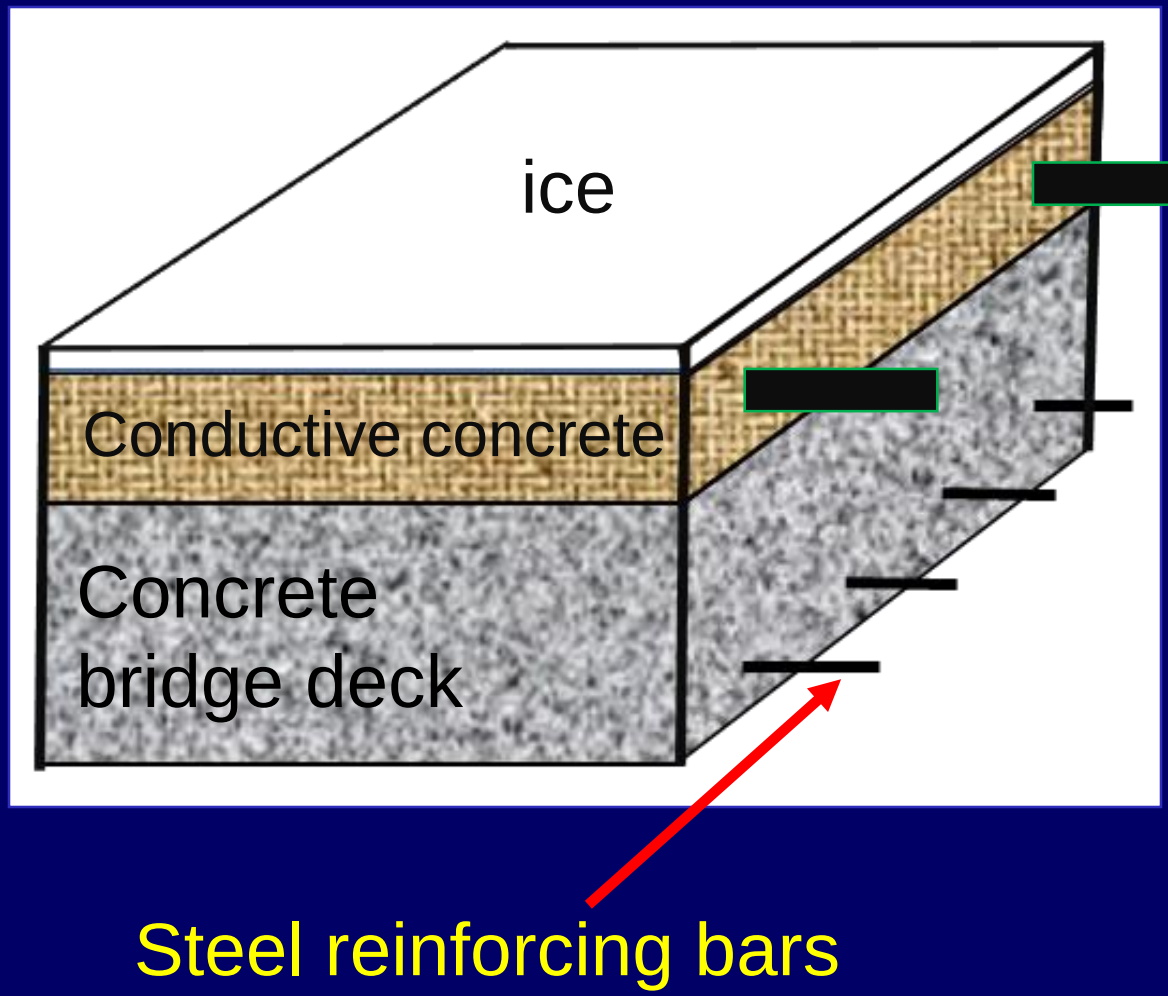


Electric heating cables



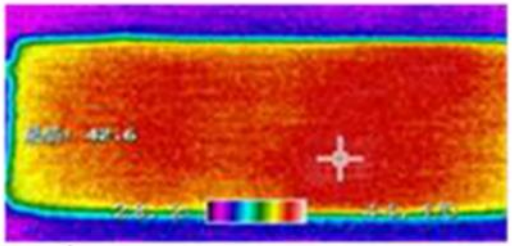
Heated fluid hydronic System

Conductive Concrete Deicing Concept

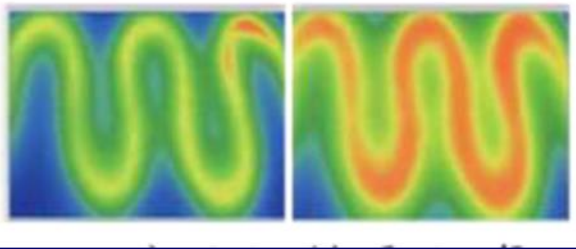


Comparison of Deicing Systems

	Electric Heating Cables	Heated Fluid/Gas Hydronic	Conductive Concrete
Energy Source	Electric	Natural gas/propane + electric	electric
Heat Transfer Efficiency	< 70%	< 50%	> 90%
Required Floor Space	None	Mechanical room, $100-500/sf	None
Power Density	22-30W/sf	28-30W/sf	12-30W/sf
Energy Consumption (sidewalk)	350 kWh/m^2	150 kWh/m^2	3.0 kWh/m^2
Energy Consumption (bridge deck)	600 kWh/m^2	260 kWh/m^2	9.5 kWh/m^2
Installation Cost	$25/sf	$35/sf	$18/sf
Operating Cost	$1.50/sf	$0.40/sf	$0.04/sf
Maintenance Cost	Cable fault detection and repair	Glycol leaks, notify EPA	Maintenance free
Construction Time	Days/weeks	Weeks/months	Days



Conductive Concrete



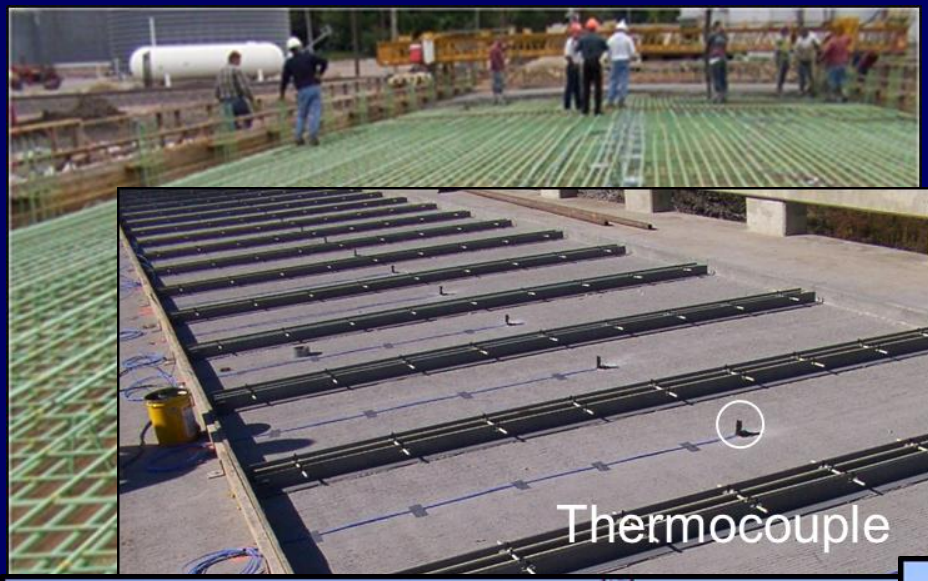
Hydronic System

Roca Spur Bridge

built in 2002

- Located about 15 miles south of Lincoln, Nebraska, on Highway 77 South.
- Roca Spur Bridge is a three-span slab bridge with a 45.7m (150 ft) long and 11m (36 ft) wide concrete deck.
- The bridge has a 36 m (117 ft) long and 8.5 m (28 ft) wide conductive concrete inlay.
- The inlay consists of 52 individual 1.2m x 4.1m (4 ft x 14 ft) conductive concrete slabs.

Bridge Deck Construction



Consistent Deicing Performance

Deicing Performance Data

Storm Date	Snow depth (in.)	Air temp. (^oF)	Wind (mph)	Energy (kW-hr)	Unit Cost ($/ft^2)	Peak Power Density (W/ft^2)
Dec 8-9, '03	6.5	20.7	16.2	2,023	0.050	40.04
Jan 25-26, '04	10.1	14.9	14.4	2,885	0.070	30.74
Feb 1-2, '04	5.7	14.4	11.1	2,700	0.066	26.57
Feb 4-6, '04	7.8	19.2	11.5	3,797	0.093	35.94
Jan 2-5, '05	8.5	15.6	14.3	3,128	0.076	33.01
Feb 6-8, '05	4.6	17.3	12.7	3,327	0.081	32.25
Mar 18-21, '06	9.9	32.5	16.2	2,786	0.068	29.97
Jan 13-14, '07	3.3	10.9	21.7	2,366	0.058	18.86
Jan 20-21, '07	6.0	19.4	17.4	2,573	0.063	30.19
Feb 12-13, '07	3.8	17.6	16.2	2,653	0.065	33.54
Mar 1-3, '07	7.1	29.8	19.9	2,893	0.071	36.79

Deicing Performance Data (cont.)

Storm Date	Snow depth (in.)	Average Air temp. (^oF)	Wind (mph)	Energy (kW-hr)	Unit Cost ($/ft^2)	Peak Power Density (W/ft^2)
Dec 5-7, '07	3.5	22.5	20.5	2,866	0.070	35.02
Jan 15-18, '08	3.8	18.1	24.8	2,445	0.059	34.56
Feb 4-7, '08	4.6	21.9	22.4	3,046	0.074	36.98

Operating cost

Energy consumption during a major storm:
Average = 1,000 kW-hr/day
Total Cost = $85/day

Utility cost = $0.08 per sq. ft. of deck surface

Award-winning Bridge Project

Discovery CHANNEL

The Economist

- The Economist, 9/29/06

ASCE
American Society of Civil Engineers

- Best paper award, 2006-2008 Cold Regions Engineering

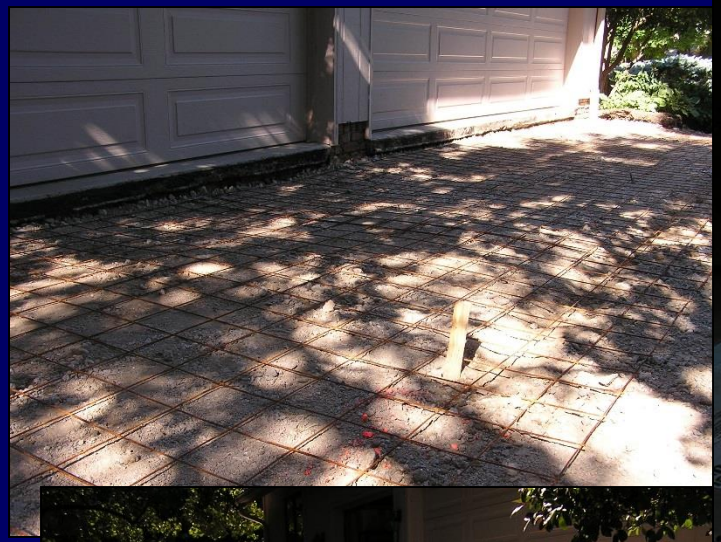
aci

American Concrete Institute Award of Excellence, 2004

- Discovery Channel Magazine August 2010

Patents in 5 countries

Heated Driveway Entrance



Heated Driveway – under 48 V AC

Deicing performance

December 8, 2011

- **Ambient temp = 22 F, the total current = 36 Amps under 48 V AC. The slab temp was about 38 F.**
- **The heated pad is 7 ft wide and 30 ft long. Output power density = (36x48)/(7x30) = 8.2 W/ft^2.**
- **Energy consumption per day = 40 kW-hr. $0.075/kW-hr x 40 kW-hr = $3/day.**
- **Powered by a 3 kVA transformer.**

Parking Ramps – Harbin Institute of Technology built in 2012

- The East and North Ramps of the parking garage at the Architectural Design and Research Institute, Harbin, China.
- Both ramps were overlaid 3.5-in. conductive concrete for deicing.
- The East Ramp is 135 feet long and 18.5 feet wide, and the North Ramp is 135 feet long and 25 feet wide.
- Both ramps have a steep slope of 15%.
- Powered by 48 V AC via transformers connected to a 220 V AC source.

Construction Sequence

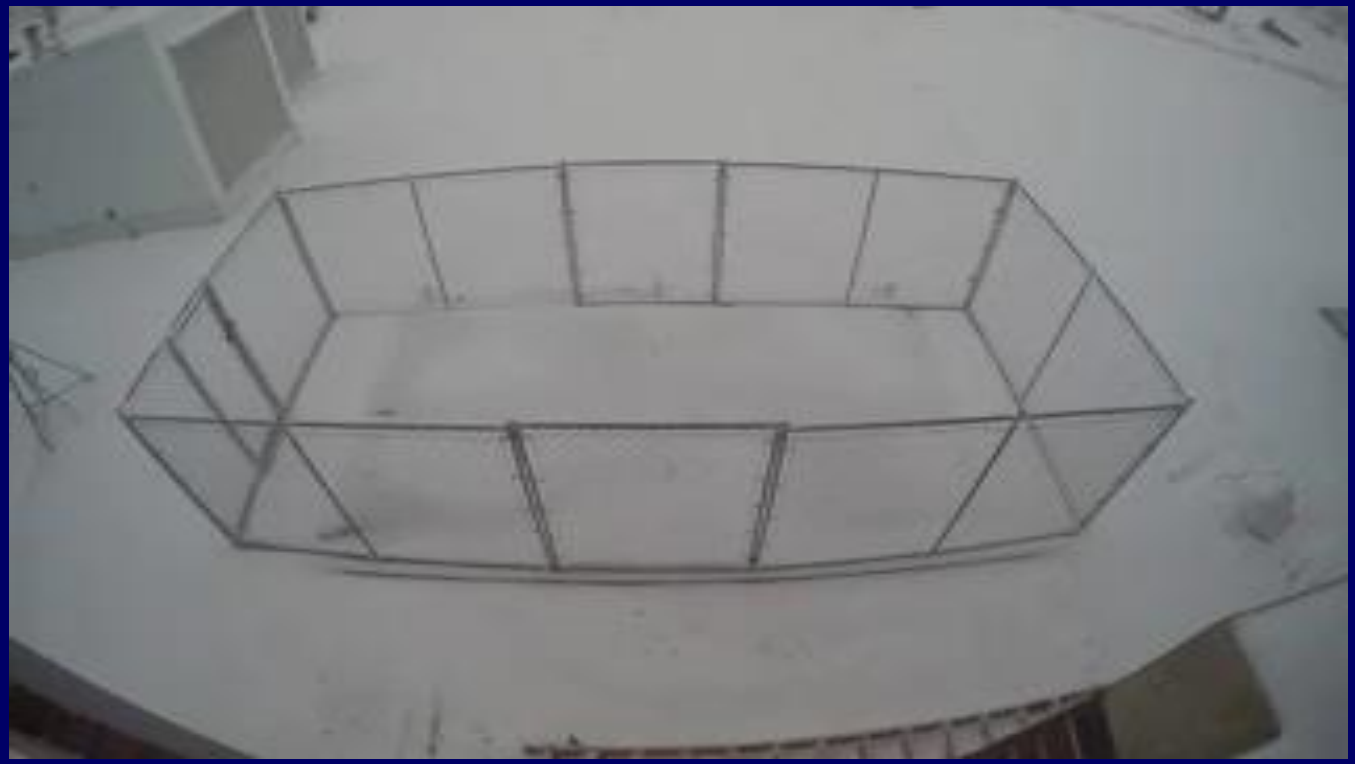

UNIVERSITY OF
Nebraska
Lincoln
FEDERAL AVIATION
ADMINISTRATION

10 ft x 20 ft Test Pad Deicing Data

Storm Date	Snow depth (in.)	Air temp. (^oF)	Wind (mph)	Energy (kW-hr)	Unit Cost ($/ft^2)	Peak Power Density (W/ft^2)
Dec 24-25, '15	7.0	23.4	8.5	45.9	0.021	15.5
Dec 27-28, '15	4.2	13.6	18.6	69.8	0.031	14.4
Jan 25, 2016	4.0	25.2	16.5	73.4	0.032	13.0
Feb 2-3, '16	4.9	12.9	12.4	84.9	0.037	11.8

Power source: 3-phase, 208 V AC, 30 A capacity

Time-lapse Video (4 hours) – Dec 28, 2015



Snow (mm)	Air temp. (^{o}C)	Wind (km/hr)	Energy (kW-hr)	Unit Cost ($/m^2)
107	-10.2	30	69.8	0.33


THANK
YOU