First Large Scale Demonstration Project
Electrically Conductive Concrete Heated Airport Pavement System at Des Moines International Airport: Design, Construction and Performance

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Executive Summary: PEGASAS Project #1
Heated Airport Pavements

Lead Investigators: Halil Ceylan (PEGASAS Point of Contact) (Iowa State University) and John Haddock (Purdue University)

Maintaining operational safety and status of airport runways during snowfall events is a challenging issue that many airports are grappling with. The surface traction of pavement is dramatically influenced by frozen precipitation in the form of ice, snow, or slush. This can seriously hamper smooth air traffic management operations and cause traffic delays at other airports. It is imperative that both small and large airports maintain operational status during snowfall events to support the existing operations.

Over the past decade, a number of national and international research studies have investigated the use of alternative energy for anti-icing, deicing, and snow removal from bridge decks and highway pavements. Reportedly some efforts have been investigated using geothermal hydraulic and battery based electrical systems with limited success. The Federal Aviation Administration (FAA) has expressed an interest in investigating the concept of heating pavements at airports to assist with snow and ice removal, recognizing the limitations of current practice and research on heated pavement technology.

In this project we propose a eight-pronged approach including Task 1-A: Energy and financial viability, Task 1-B: Hybrid heated airport pavements, Task 1-C: Phase change materials for concrete, Task 1-D: Advanced construction techniques, Task 1-E: Phase change materials for asphalt, Task 1-F: Electrically conductive asphalt concrete, Task 1-G: Superhydrophobic asphalt concrete, and Task 1-H: Full-scale demonstration. The expected benefits of the project are:

- A better understanding of the relative costs of installing and running heated pavement systems with respect to the current systems, along with benefits to worker safety and operating efficiency to the airport,
- An approach to decision making regarding whether or not to install such a system, and selection of the systems that may be beneficial,
- Improved operational efficiency at airports, reduced costs and impacts of snow and ice removal,
- Expedited and efficient snow and ice removal operations that can reduce traffic delays, especially at large air-ports,
- An approach by not possessing any environmental concerns like the contamination of nearby bodies of water and foreign object debris/damage (FOD) to aircraft engines,
- Reduction of downtime required to clear ice and snow,
- Improve safety for ground crews servicing the aircraft at the gate area, improve safety of passengers embarking/disembarking the aircraft.

The overall impacts of this research will make winter air travel faster, more affordable, more accessible, more sustainable and safer for all parties involved.
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• Motivation, Need and Objective(s)

• Approach, Methods and Design

• Construction and Performance Evaluation

• Summary
Motivation

Delta flight skids off LaGuardia runway, stops feet from frigid waters

Courtesy: CNN

Courtesy: Fox News

Courtesy: ABC News

Courtesy: NBC News

Courtesy: Reuters

Courtesy: WSJ

Courtesy: WSB-TV News

Courtesy: NY Daily News
Delta Airlines plane skids off JFK runway

By Philip M. Mossing, Priscilla DeGregory and David K. Li

January 5, 2014 | 9:16am

The Delta plane moments after it skidded off the runway at JFK.

Motivation (Cont’d)
Flight cancellations spike Friday, near 8,000 for the week

News

JFK Airport Runways Reopen Following Snow Squall
February 22, 2016 6:12 PM

Nearly 8,000 flights have been cancelled because of the snow storm including some out of Houston. KHOU Staff, KHOU.com 1:23 p.m. CST January 27, 2015

HCUSTON – About 60 million people are waking up to snow across the northeast but the blizzard predictions were not as severe as predicted.

Travel bans across several states are being lifted. There was still snow, but clearly not as much as expected.

Airlines cancelled nearly 8,000 flights, which impacted travelers flying in and out of Houston airports.

At George Bush Intercontinental Airport, many connecting flights across the country were affected.

UPDATE: Black Ice, Accidents, Speed Restrictions, Airport Delays As New Jersey Battles Storm Impact

By Tom Davis (Patch Staff) March 2, 2015 at 6:27am

 Courtesy: patch.com
• Snow and ice hits airport!
• Got heated pavements?
Heated Airport Pavements (Cont’d)

- Snow and ice free pavement surface
Heated vs. Unheated Aircraft Stands

Oslo - Gardermoen Int’l Airport in Norway (Hydronic heating)
Heated Airport Pavements: Types

- **Hydronic pavement heating**
  - Direct-use of geothermal waters for the fluids is most efficient but may be limited to areas close to tectonic-plate boundaries
  - Other locations need to consider ground source heat pumps, heat exchangers, or boilers to boost efficiency and reduce the operational costs
  - Alternative heat sources, such as waste heat, may be utilized if a reliable supply over the whole design lifetime is guaranteed

- **Electrically heated pavements**
  - Insulated conductors are embedded in the pavement, such as heating cables or grid/mesh mats
  - Conductive materials are added to the pavement material mix, electrical energy is applied through uninsulated conductors, and the pavement serves as the heat source

(FAA AC 150/5370-17 2011)
• To gain a comprehensive and practical understanding of heated concrete pavement operations through in-situ field demonstration and analytical studies

• Significant problems to be addressed include
  – Practical design alterations
  – Modifications to existing construction procedures
  – Placement issues
  – Safety of electrical systems with regard to stray currents
  – Pavement performance degradation issues resulting from thermal-mechanical-electrical interactions during heated pavement operations, etc.
• Motivation, Need and Objective(s)

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• Summary
Proposed Location

- Proposed location: Des Moines International Airport (DSM), North General Aviation (GA) Apron
• Meetings with airport manager and staff
• Proposed ECON system:
  – Slab 1: Two-layer structure
  – Slab 2: Two-layer structure

1.5”x1.5”x1/8” Electrodes

Two-layer structure

8” P-209 Aggregate base course

4” P-501 PCC

3.5” ECON layer

Subgrade
• Utilize P-501 PCC mix design provided by Foth Infrastructure and Environment, LLC and Kingston Services, LLC for bottom layer in both slabs
  – Design strength: 650 psi flexural strength
  – W/CM: 0.43
  – Air content: 6.0%
  – Slump: 1.5 in.
  – Unit weight: 144 pcf
• ECON mix design recipe
  – Based on P-501 PCC mix design provided by Foth Infrastructure and Environment, LLC
  – Considering use of ready mix concrete for paving
• ECON mix design (ECON mix at ISU PCC lab)
Electrodes, Sensors, and Other Materials

- **Electrodes** *(12 electrodes)*
- **Sensors**
  - Thermocouple type T *(68 sensors)*
  - 5TE moisture, temperature, and electrical conductivity sensor *(4 sensors)*
  - Strain gages, Geokon *(16 sensors)*
  - Digital temperature and humidity sensor SHT71, Sensirion *(4 sensors)*
  - Wireless temperature sensors *(2 sensors)*
  - Wireless humidity sensors *(2 sensors)*
- **Sensor trees** *(26 sensor trees)*
- **Sensor chairs** *(16 sensor chairs)*
- PVC pipe and junction box
• Electrodes layout plan
  – Placing 6 electrodes per a slab
• Placing fiberglass rebar on top of electrodes to prevent cracking due to environmental load.

Fiberglass rebar

Electrode

Slab 1

Slab 2

Plastic zip to tie the fiberglass rebar with the electrodes

¼ in. Fiberglass rebar

15 in.
• Placing fiberglass rebar on top of electrodes to prevent cracking due to environmental load

[Diagram showing placement of fiberglass rebar and electrodes with annotations: ¼ in. Fiberglass rebar, Plastic zip to tie the fiberglass rebar with the electrodes, Slab 1, Slab 2, Electrode]
• Sensor layout plan
Instrumentation Design, 3D Plan

**Box 1 (Inside Building):**
- Ruggedized laptop and 2G Gateway
- AC/DC power converter
- Arduino and PCB for 68 temperature sensors
- Campbell Scientific system for strain gages
- EK H4 for Sensirion sensor (Temp./RH)
- EM50 data logger for Decagon sensor (Temp./Moisture)

**Box 2 (Inside Building):**
- Two 3 in. PVC conduits to house wires for sensor systems
- One 2 in. PVC conduit for electrical wires (To power electrodes)
- 6 current sensors, 6 voltage sensors, and 6 resistance sensors for 6 electricity cables for 12 electrodes
- Wireless temperature and humidity sensors (extended probes with cables)
- Holes are used to pass the wires through (Diameter: 2 in, Length/Height: 4 in)

- Two boxes are located inside the building
- Two 3 in. PVC conduits to house wires for sensors system and each PVC conduit will carry 50 wires (total 100 sensors)
- One 2 in. PVC conduit to house electrical wires (electrodes) (total 6 wires for 12 electrodes)
• Utilize existing electrical power supply nearby building 69 on the inside
  – Single-phase panel 120/240V, 200 A power is available in the building 69 (hangar)
  – The electrical control box consists of:
    • Power meter
    • Temperature sensing
    • Power switching on/off unit
    • Circuit breakers
Power Supply System (Cont’d)

- Power supply and data acquisition systems
Power Supply System (Cont’d)

- Power supply

Circuit breaker 60A for each slab
Contactor
Single-phase panel 120/240V, 200 A
Remote Control System

DSM International Airport Heated Pavement System Automation Flowchart

Control Logic

If \( T < 35^\circ F \) \( \rightarrow \) ON
Else if \( T > 45^\circ F \) \( \rightarrow \) OFF

On-Site PC
DSM Intl

Off-Site Remote Monitoring & Control

Arduino

Auto ON/OFF based on Temp

Power switch Tail-II
120 V – 240 V

Temperature Sensors \( \times 2 \)

Single Phase AC
120 V – 240 V, 200Amp

Heated Pavements
1. Install boxes and outside at camera locations and stub conduit through wall. Mount cameras 10' to 12' off ground.
2. Extend power from near by panel to outlet below each camera stub through location and install duplex outlet for power brick.

Surveillance Camera
• Motivation, Need and Objective(s)

• Approach, Methods and Design

• Construction and Performance Evaluation

• Summary
• Step 1: Prepare 8 in. of P-209 aggregate base course
• Step 2: Placing PVC conduits (10 of them, 5 for each slab) to house wires for sensor systems and electrodes
  – Diameter: 2 in, Length/Height: 4 in
Construction Steps (Cont’d)

- Step 3: Placing 4 in. P-501 PCC on 8 in. of P-209 aggregate base course
• Step 4: Placing three wireless sensors
  – Two wireless humidity industrial sensors (one per slab)
  – One wireless temperature sensor (mounted on the wall)
Construction Steps (Cont’d)

• Step 5: Installing two surveillance cameras
• Step 6: Marking sensors location and drilling holes for sensor trees

Holes to house wires for sensors system and electrodes
Construction Steps (Cont’d)

• Step 7: Placing PVC conduits (10 of them, 5 for each slab) to house wires for sensor systems and electrodes
  – Diameter: 1 in, Length/Height: 180 in
Construction Steps (Cont’d)

• Step 8: Placing sensors
• Step 9: Placing the wires through PVC conduits and connected to the data logger
• Step 9: Placing the wires through PVC conduits and connected to the data logger (Cont’d)
• Step 10: Installing the power supply (contactors) and electrical sensors
• Step 11: Placing fiberglass rebar on top of electrodes to prevent cracking due to environmental load

Fiberglass rebar is fixed by cable ties

Nylon cable ties
Step 12: Clearing and preparing the ECON slabs before paving
  – Cleaning the surface by using air-blower
• Step 12: Clearing and preparing the ECON slabs before paving (Cont’d)
  – Distributing the wires bundle to prevent cracking from edges
• Step 13: ECON mixing at the ready mix plant
  – Date: 11/04/2016
Construction Steps (Cont’d)

• Step 13: ECON mixing at the ready mix plant (Cont’d)
  – Delivery of the ECON mixture
• Step 14: Preparing and placing concrete screed
• Step 15: ECON paving
  – Paving time: 2:30 PM, Date: 11/03/2016
Construction Steps (Cont’d)

• Step 15: ECON paving (Cont’d)
• Step 15: ECON paving (Cont’d)
Construction Steps (Cont’d)

• Step 15: ECON paving (Cont’d)
Construction Steps (Cont’d)

• Step 15: ECON paving (Cont’d)
Construction Steps (Cont’d)

• Step 15: ECON paving (Cont’d)
Construction Steps (Cont’d)

• Step 15: ECON paving (Cont’d)
• Step 15: ECON paving (Cont’d)
• Step 16: Visual observation next day after ECON paving
  – No crack was observed on ECON surface
Full-scale demonstration of heated portland cement concrete pavement systems: Des Moines international airport heated concrete pavements
Outline

• Motivation, Need and Objective(s)

• Approach, Methods and Design

• Construction and Performance Evaluation

• Summary
• Heated pavements are viable options from economic, energy consumption, and environmental sustainability perspectives

• Efficiency of heated pavements could be improved through:
  – Improving material properties and performance (i.e. ECON, superhydrophobic materials, and PCM)
  – Integration of advanced construction techniques

• Economic analysis results greatly depend upon the size of the airports in terms of number of aircraft operations and pavement area
  – Large hub airports could gain more financial benefits
Summary: Overall Benefits

• Facilitates expedited and efficient snow and ice removal operations that can reduce traffic delays, especially at large airports

• Eliminates the risk of airplanes skidding off the runways, high-speed taxiways, etc.
  – No accidents, injuries or fatalities!

• Reduces the downtime required to clear ice and snow

• Improves safety for ground crews servicing the aircraft at the gate areas

• Improves safety of passengers embarking/disembarking the aircraft
• Improves air travel capacity during winter operations. Utilization of HPS helps keep the airports open and accessible during winter operations enabling safe and happy travels for the passengers

• Reduction in time required to clear snow/ice in priority areas

• Provides a platform for the development of innovative anti-icing systems such as nanostructured superhydrophobic coatings and systems, conductive paving materials, etc.

• Provides efficient operation time window, i.e., the HPS deicing operation can be automated to start and end exactly for the duration of ice and snow formation
  — Heating process can be initiated ahead of ice/snow storm and can be automated by using sensor systems
• Reduces the amount of labor and equipment costs associated with using/applying deicing methods

• A viable option from an energy or financial viability perspective for achieving pavement surfaces free of ice/snow without using mechanical or chemical snow and ice removal methods
  – Benefit-to-cost ratios are greater than 1.0 for a large number of airports studied!

• It is anticipated that with the installation of HPS the passengers’ lost time would substantially decrease
  – Operation costs can be reduced by judicious use of HPS and appropriate weather monitoring. Advancements in HPS technology and construction practices are expected to greatly bring down the installation costs
Thank You!
Questions & Comments?