First Large Scale Demonstration Project

Electrically Conductive Concrete Heated Airport Pavement System at Des Moines International Airport: Design, Construction and Performance

Presented by
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  - Jeffrey S. Gagnon, P.E., (FAA)
  - Benjamin J. Mahaffay, P.E., TPOC (FAA)
  - Charles A. Ishee, Ph.D., P.E., former TPOC (formerly at FAA)
  - Donald Barbagallo, P.E., former TPOC (retired, formerly at FAA)
  - William A. Crossley, Ph.D., Director (PEGASAS, Purdue)
  - Richard Wlezien, Ph.D., former Co-Site Director (PEGASAS, ISU)
  - Julienne M. Krennrich, Ph.D., former Co-Site Director (PEGASAS, ISU)
  - Diane M. Meyer, (ERI, ISU)
- Iowa State University
- Purdue University

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Acknowledgements: Airports

- Des Moines International Airport, Des Moines, IA (DSM)
  - Bryan Belt, Mark Duffy, William Konkol, and others
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  - Paul M. Sichko
- Port Columbus International Airport, Columbus, OH (CMH)
  - Joshua Burger
- Kent State University Airport, Kent, OH (1G3)
  - Dave Poluga
- Mason City Municipal Airport, Mason City, IA (MCW)
  - David Sims

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- American Concrete Pavement Association (ACPA)
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- Central Iowa Ready Mix (Keith Kuennen)
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- GCP Applied Technologies (Allen R. Johnson)
- Iowa Concrete Paving Association (Dan King)
- Kingston Services, LLC.
- Zoltek Companies, Inc.

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.

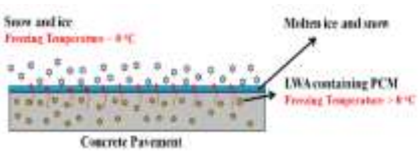
Over the past decade, a number of national and international research studies have investigated the use of alternative energy for anti-icing, deicing, and snow removal from bridge decks and highway pavements. Reportedly some efforts have been investigated using geothermal hydraulic and battery based 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:*

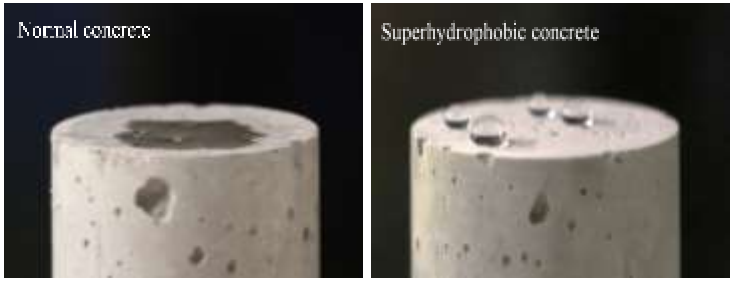
- A better understanding of the relative costs of installing and running heated pavement systems with respect to the current systems, along with benefits to worker safety and operating efficiency to the airport,
- An approach to decision making regarding whether or not to install such a system, and selection 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.

Electrically conductive concrete (ECON)



Des Moines International Airport
ECON Heated Pavement System



Superhydrophobic concrete

Participants

- Iowa State University (ISU)
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  - Sunghwan Kim, Ph.D., P.E., Co-PI
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Participants (Cont'd)

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Participants (Cont'd)

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    - Michelle Chew (CCEE), B.S. student (graduated in 2016)
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Outline

- Motivation, Need and Objective(s)
- Approach, Methods and Design
- Construction and Performance Evaluation
- Summary

Motivation

Courtesy: CNN

Courtesy: Fox News

Courtesy: NY Daily

Courtesy: ABC News

Courtesy: NBC News

Courtesy: WSB-TV News


Courtesy: Reuters


Courtesy: WSJ


Courtesy: NY Daily

Motivation (Cont'd)

Delta Airlines plane skids off JFK runway

Courtesy: NY Post

By Philip Messing, Priscilla DeGregory and David K. Li

January 5, 2014 | 9:16am

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

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NTSB: Pilot erred in runway crash that killed boy

STORY HIGHLIGHTS

- National Transportation Safety Board: Pilot error caused 2005 runway accident
- Southwest Airlines jet skidded off a runway at Chicago's Midway Airport
- The incident resulted in the death of a 6-year-old boy
- Pilot, co-pilot were unfamiliar with jet's automatic brake system, NTSB said

Courtesy: CNN

WASHINGTON (CNN) -- Federal investigators Tuesday blamed the pilot of a Southwest Airlines jet for causing the plane to skid off a runway at Chicago's Midway Airport in 2005, an accident that killed a 6-year-old boy.

We Recommend

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Motivation (Cont'd)

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Flight cancellations spike Friday, near 8,000 for the week

TODAY IN THE SKY Ben Mutzabaugh, USA TODAY 7:13 p.m. EST February 27, 2015

***Courtesy*: USA Today**

News

JFK Airport Runways Reopen Following Snow Squall

February 22, 2015 9:12 PM

***Courtesy*: CBS News**

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Airlines cancel flights as another snowstorm hits Northeast

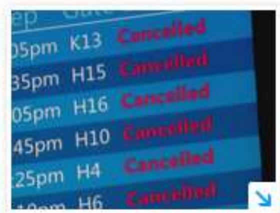
***Courtesy*: USA Today**

TODAY IN THE SKY Harriet Baskas, Special for USA TODAY 10:56 a.m. EST February 9, 2015

Nearly 8,000 flights have been cancelled because of the snow storm including some out of Houston. KHOU

KHOU Staff, KHOU.com 1:23 p.m. CST January 27, 2015

***Courtesy*: KHOU.com**



(Photo: KHOU)

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HOUSTON – 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

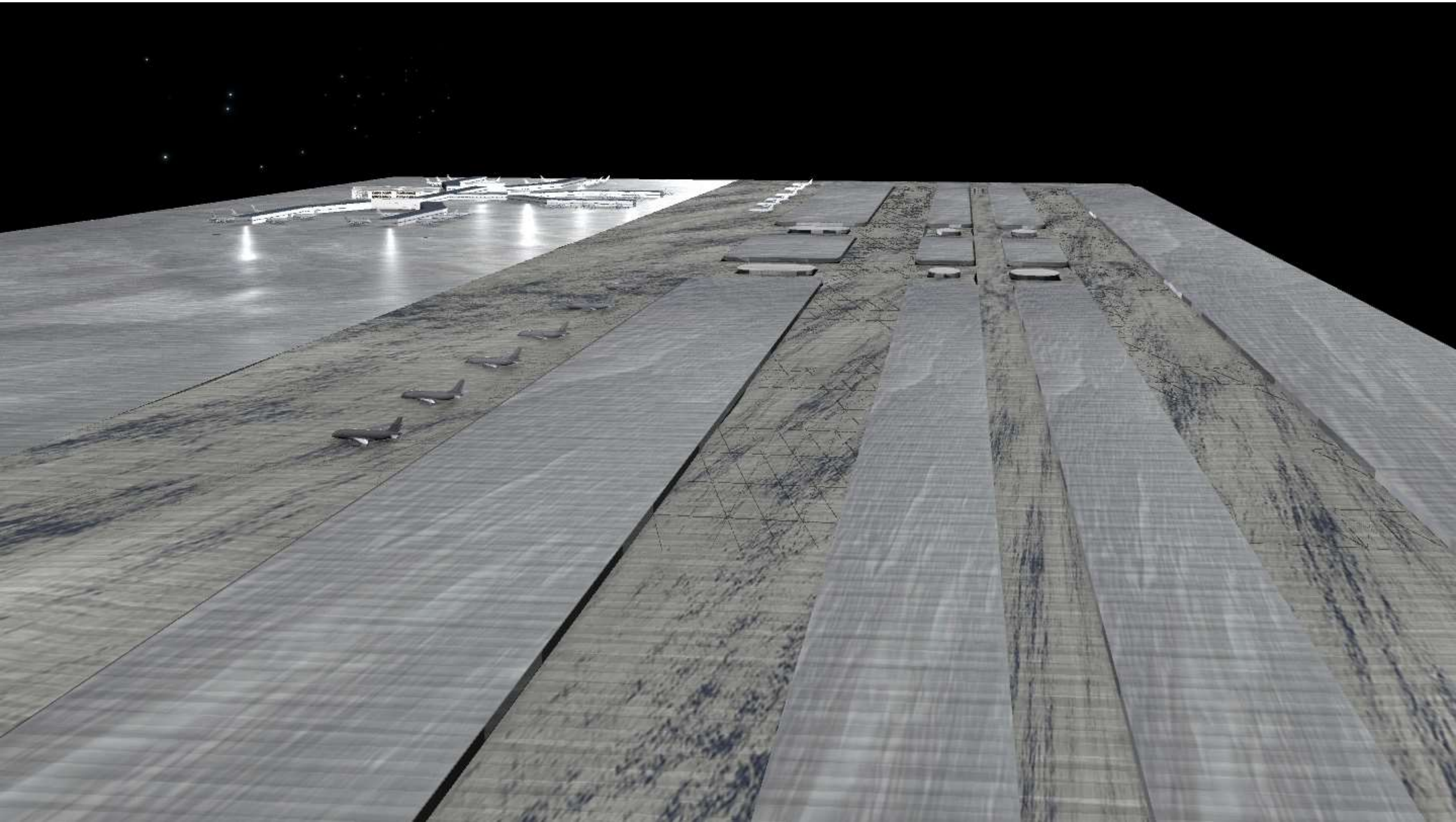
Truck fell through ice in Toms River; a list of accidents that are causing delays on roads; three-hour delays at airports.

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

***Courtesy*: patch.com**

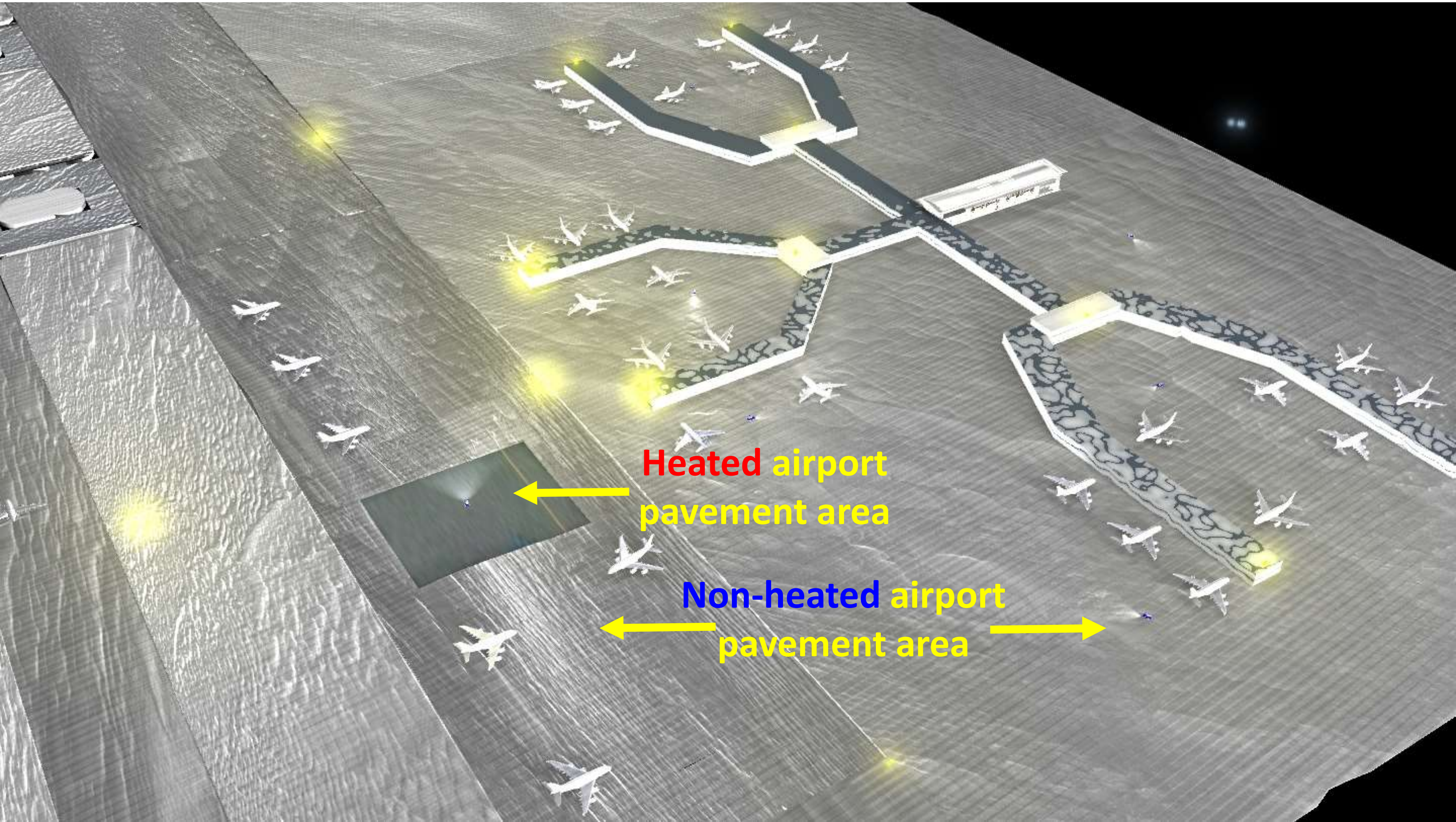
Heated Airport Pavements

- Snow and ice hits airport!



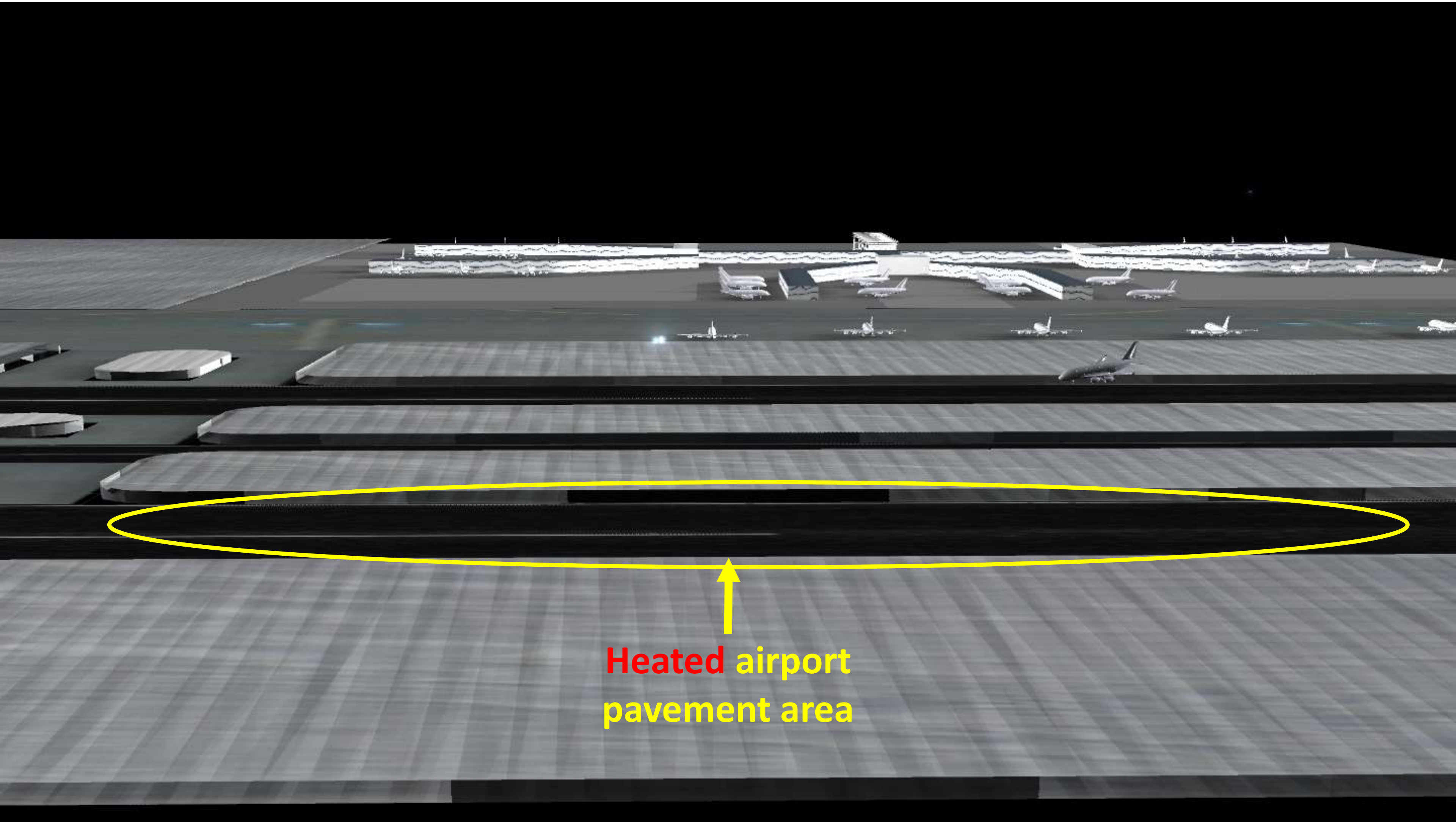
Heated Airport Pavements (Cont'd)

- 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)

(Barbagallo, 2013)

Heated Airport Pavements: Types

- FAA AC 150/5370-17, "*Airside Use of Heated Pavements*"
  - **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)

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Objective(s)

- 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.

Outline

- Motivation, Need and Objective(s)
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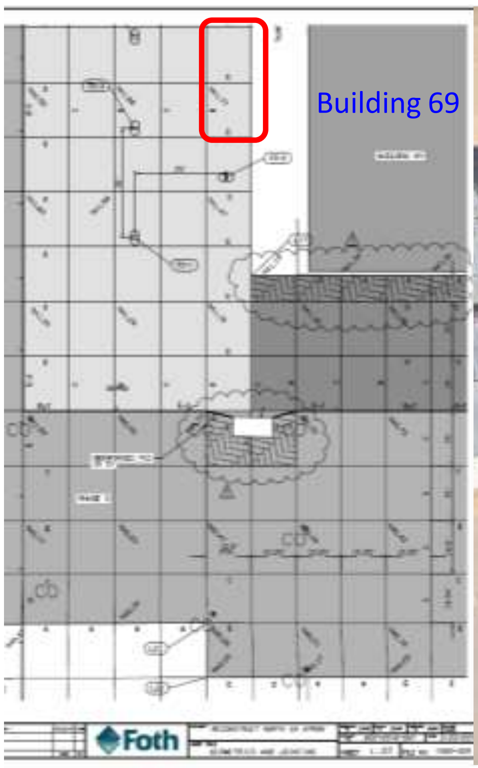
Proposed Location

- Proposed location: Des Moines International Airport (DSM), North General Aviation (GA) Apron



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Proposed Location (Cont'd)

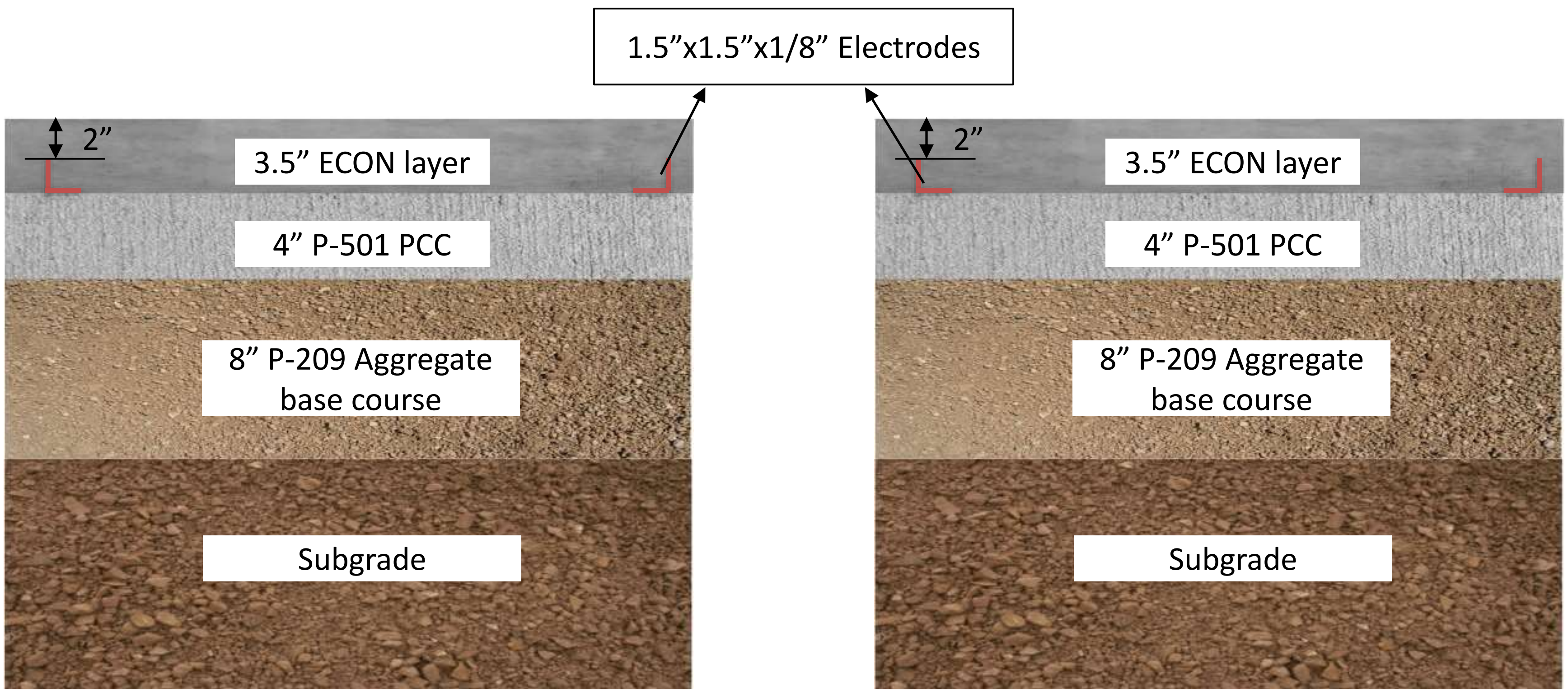
- Meetings with airport manager and staff






Proposed ECON System

- Proposed ECON system:
  - Slab 1: Two-layer structure
  - Slab 2: Two-layer structure



Two-layer structure

Two-layer structure

ECON/P-501 PCC Mix Design

- 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/P-501 PCC Mix Design (Cont'd)

- 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/P-501 PCC Mix Design (Cont'd)

- ECON mix design (ECON mix at ISU PCC lab)



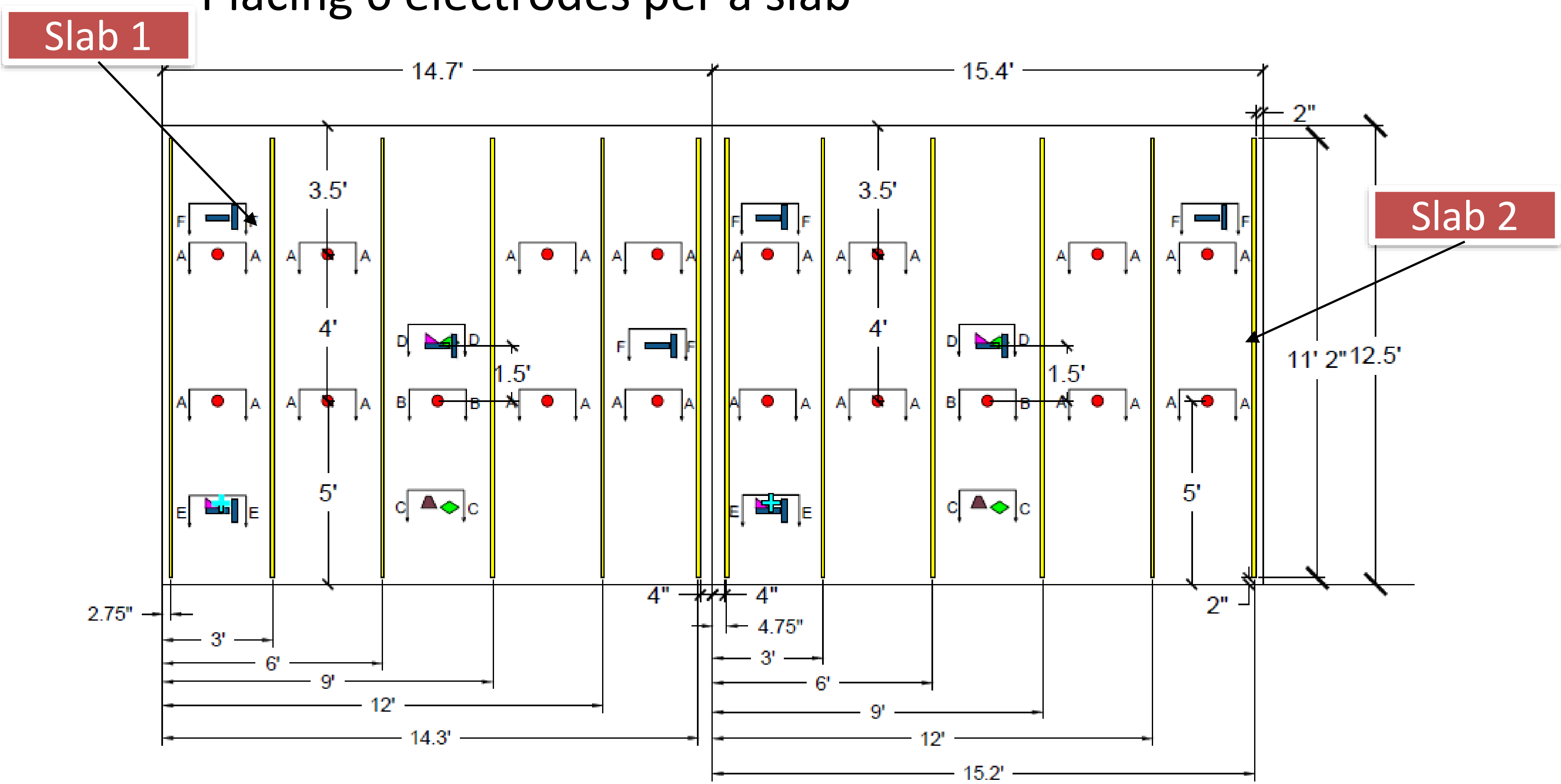


Electrodes, Sensors, and Other Materials

- 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

Instrumentation Design, 2D Plan

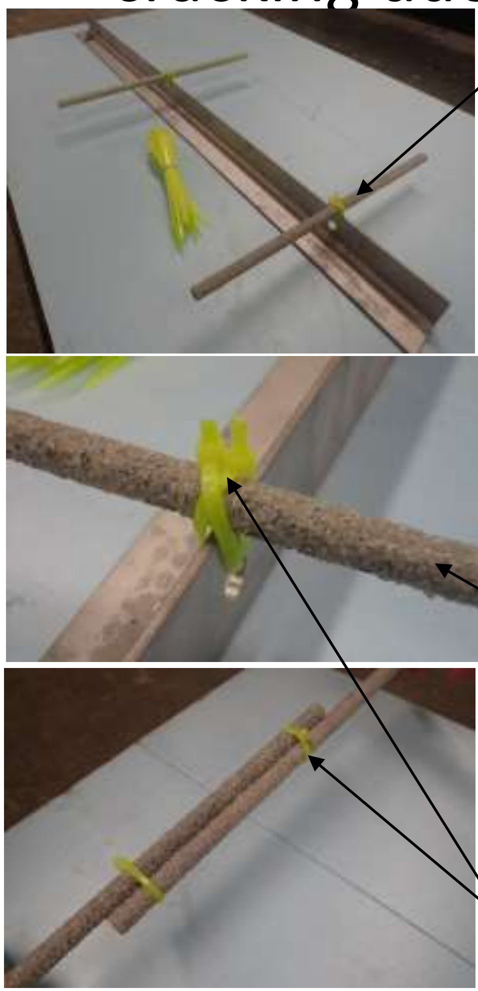
- Electrodes layout plan
  - Placing 6 electrodes per a slab

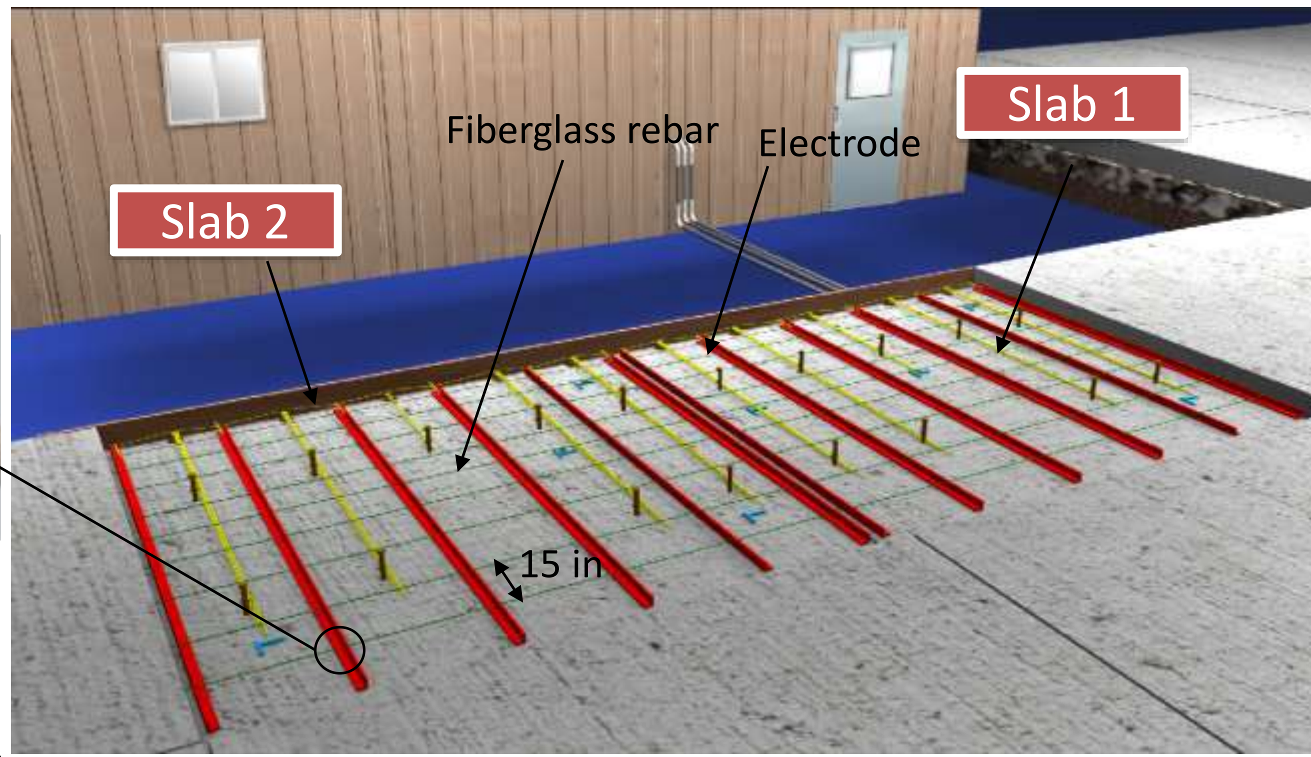


Instrumentation Design, 2D Plan (Cont'd)

- Placing fiberglass rebar on top of electrodes to prevent cracking due to environmental load

¼ in. Fiberglass rebar

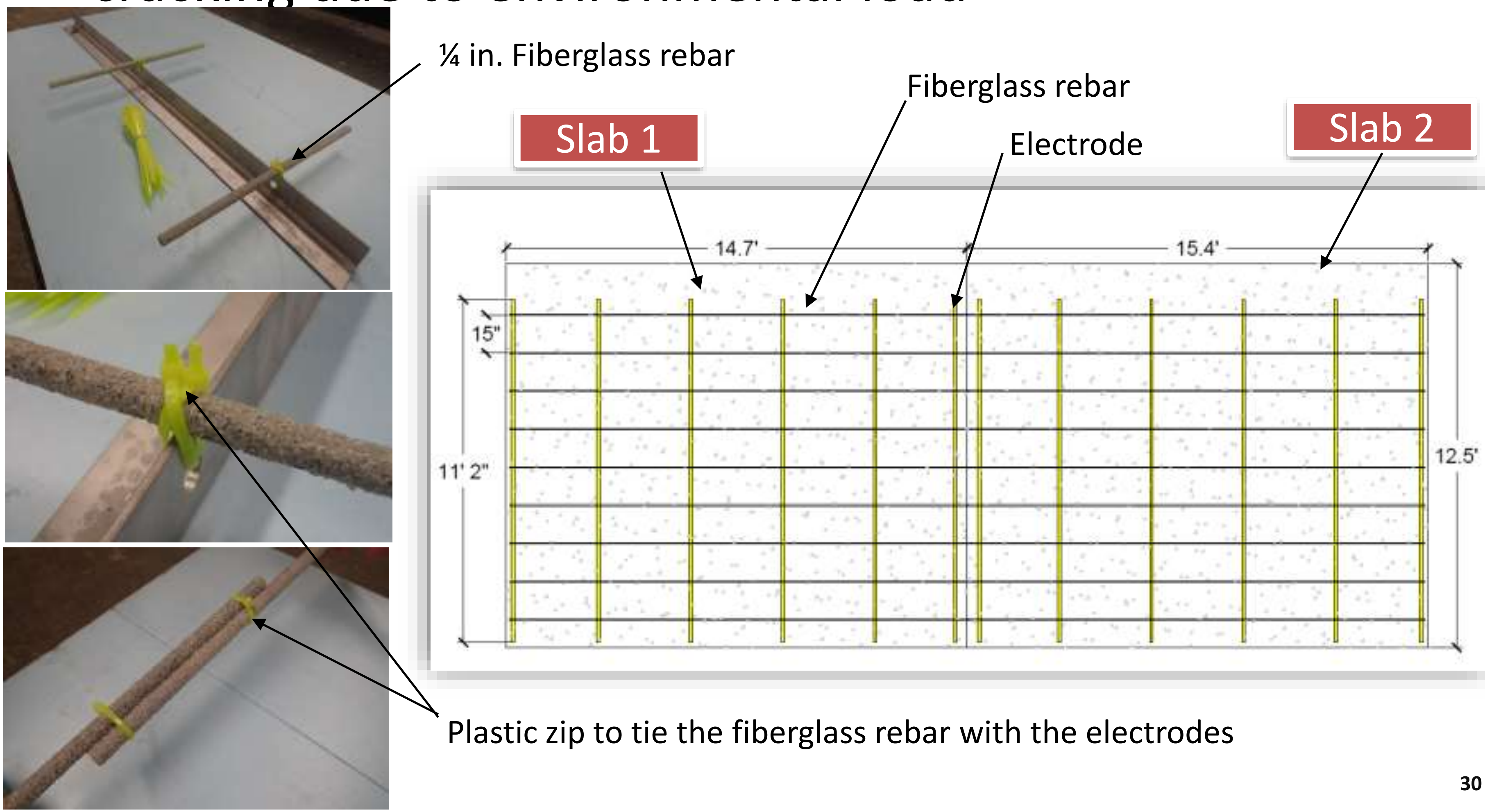




Plastic zip to tie the fiberglass rebar with the electrodes

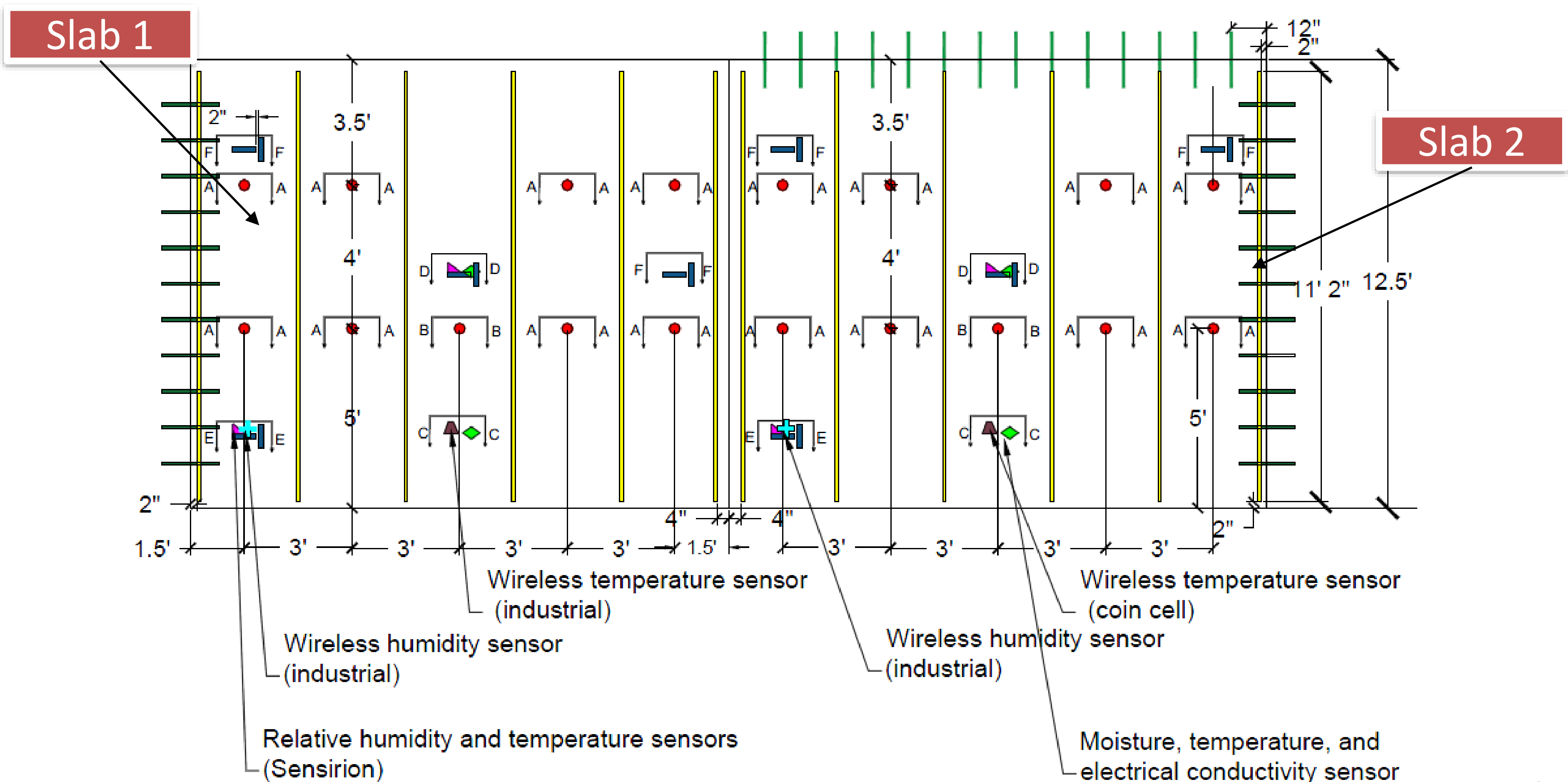
Instrumentation Design, 2D Plan (Cont'd)

- Placing fiberglass rebar on top of electrodes to prevent cracking due to environmental load

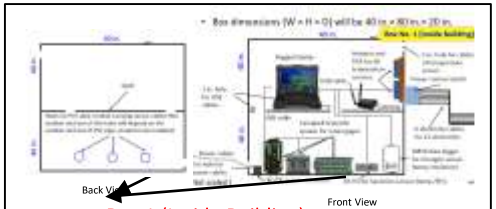


Instrumentation Design, 2D Plan (Cont'd)

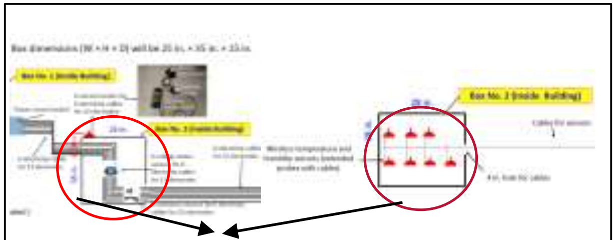
- Sensor layout plan



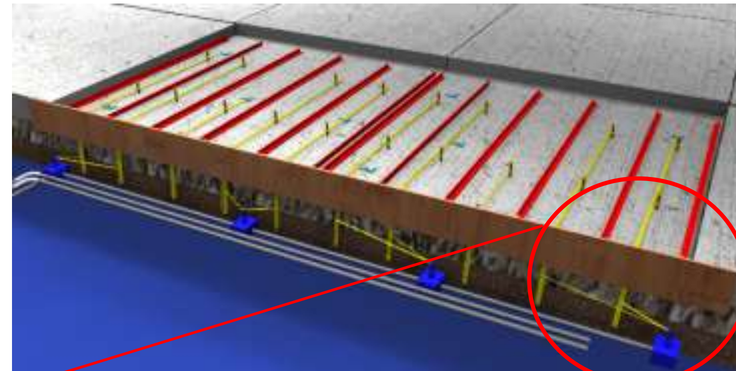
Instrumentation Design, 3D Plan

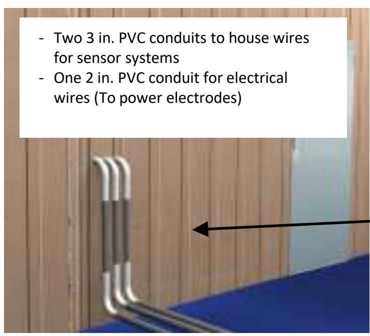


Box 1 (Inside Building):
- Ruggedized laptop and 2G Gateway
- AC/DC power converter
- Arduino and PCB for 68 temperature sensors
- Campbell Scientific system for strain gages
- EK-H4 for Sensirion sensor (Temp./RH)
- EM50 data logger for Decagon sensor (Temp./Moisture)

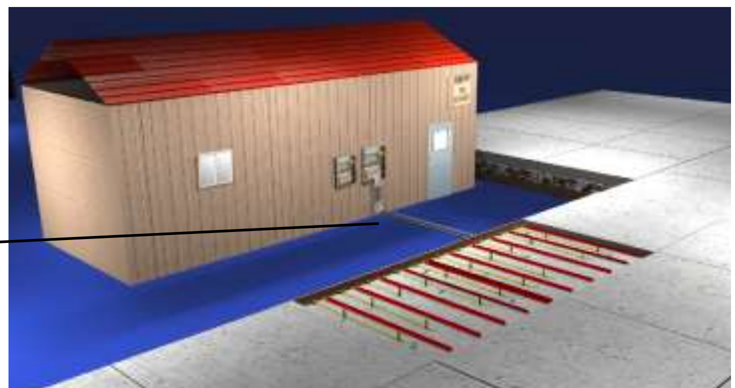


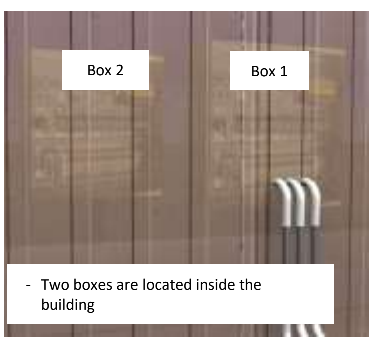
Box 2 (Inside Building):
- 6 current sensors, 6 voltage sensors, and 6 resistance sensors for 6 electricity cables for 12 electrodes
- Wireless temperature and humidity sensors (extended probes with cables)



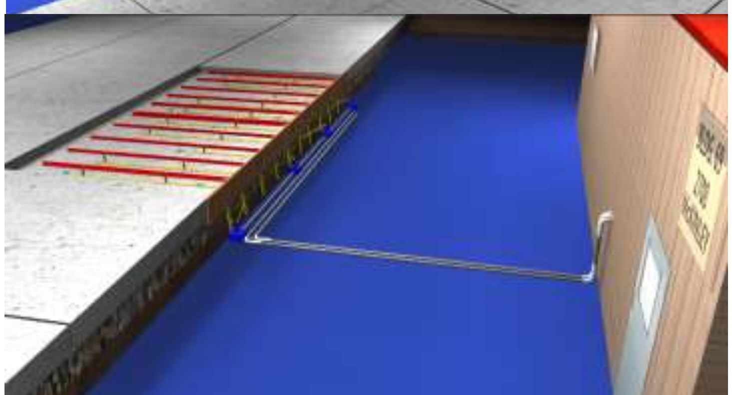


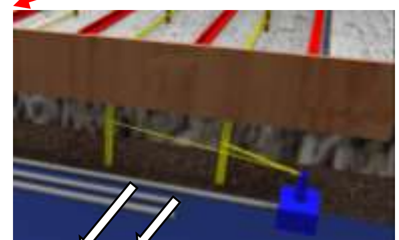
- Two 3 in. PVC conduits to house wires for sensor systems
- One 2 in. PVC conduit for electrical wires (To power electrodes)



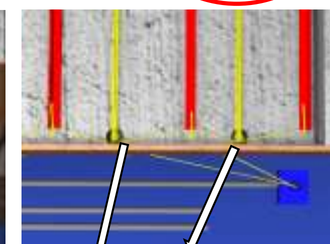


- Two boxes are located inside the building

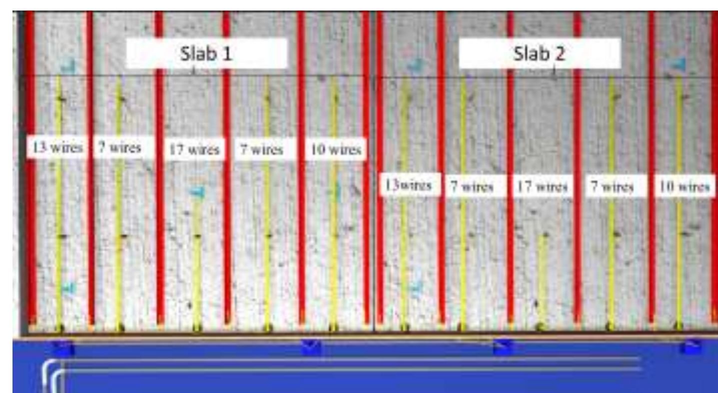




- Two 3 in. PVC conduits to house wires for sensors system and each PVC conduit will carry 50 wires (total 100 sensors)
- One 2 in. PVC conduit to house electrical wires (electrodes) (total 6 wires for 12 electrodes)



- Holes are used to pass the wires through (Diameter: 2 in, Length/Height: 4 in)



- 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

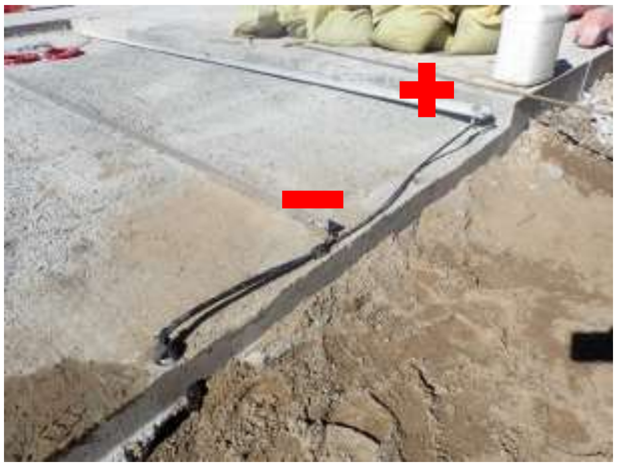

Electrical control box

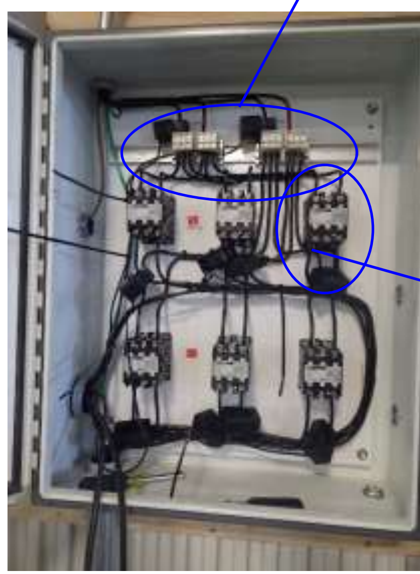
Power Supply System (Cont'd)

- Power supply and data acquisition systems

Power Supply System (Cont’d)

- Power supply





Contactor

Circuit breaker
60A for each slab

Single-phase panel
120/240V, 200 A

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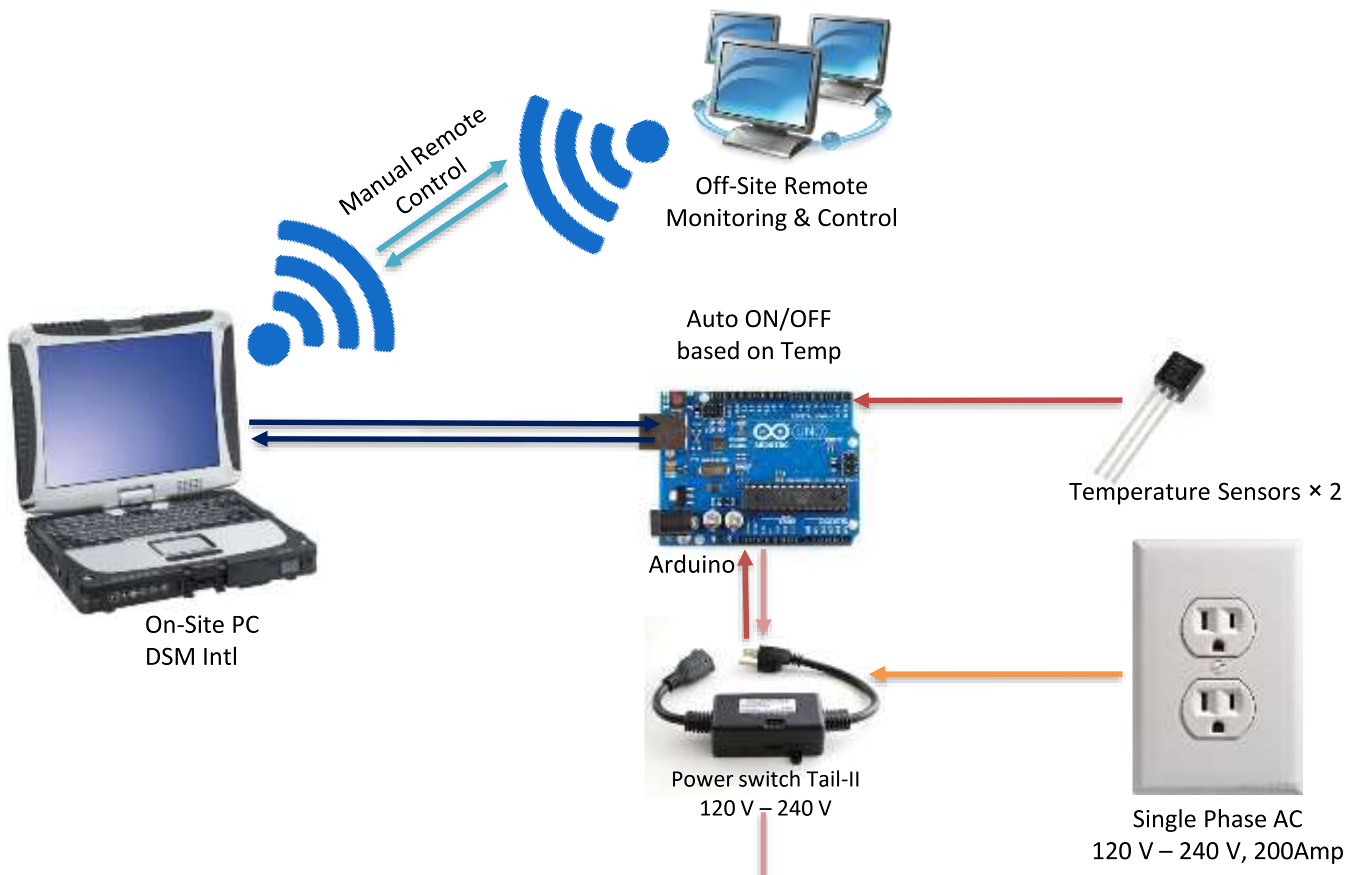
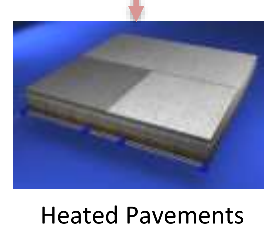
Remote Control System

DSM International Airport Heated Pavement System Automation Flowchart



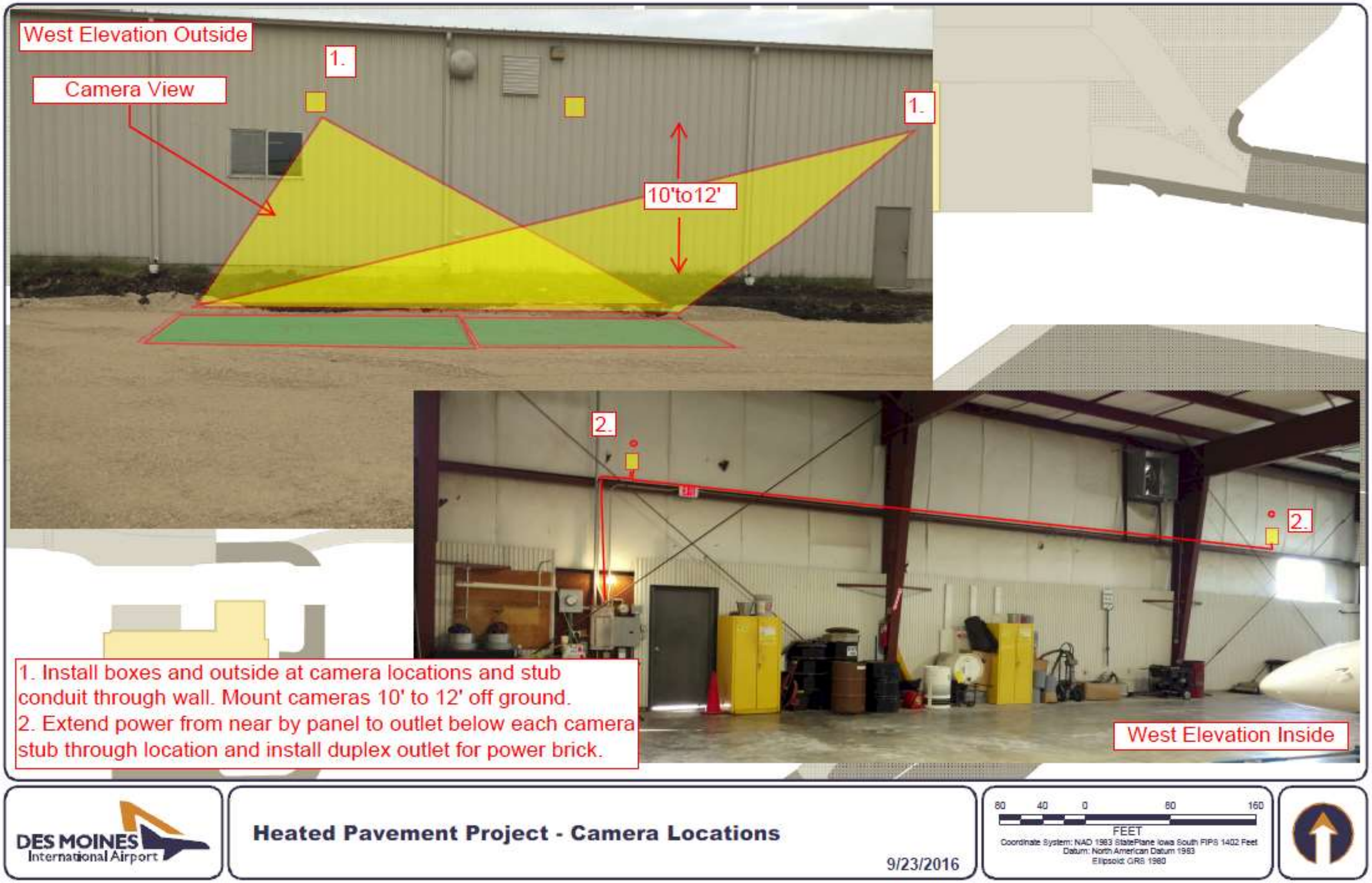


Control Logic

If T < 35ºF → ON

Else if T > 45ºF → OFF

Surveillance Camera



Outline

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Construction Steps

- Step 1: Prepare 8 in. of P-209 aggregate base course

Construction Steps (Cont'd)

- 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

Construction Steps (Cont'd)

- Step 4: Placing three wireless sensors
  - Two wireless humidity industrial sensors (one per slab)
  - One wireless temperature sensor (mounted on the wall)

Two wireless humidity sensors

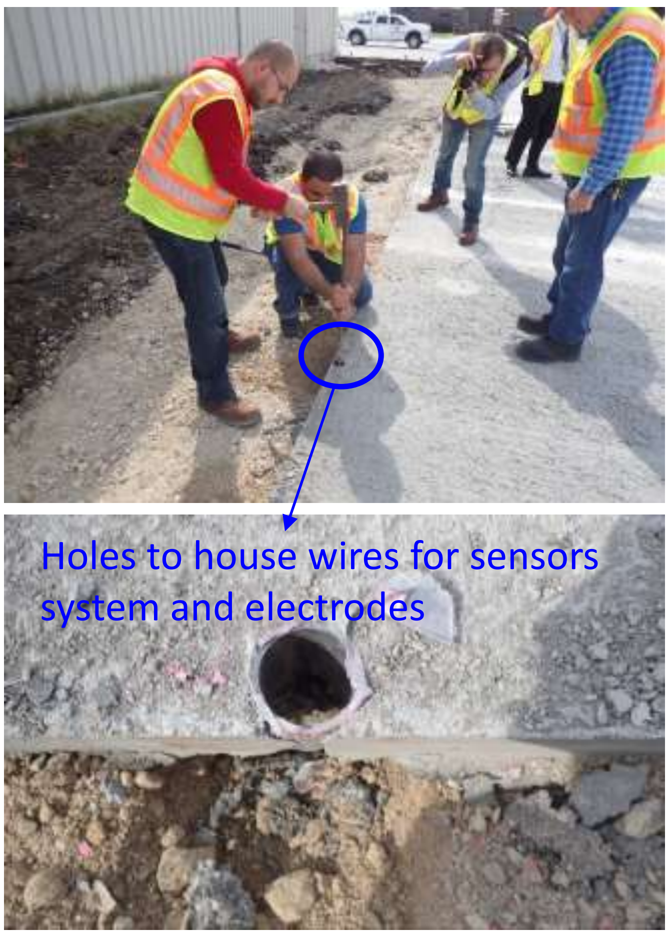
One wireless temperature sensor-coin

Construction Steps (Cont'd)

- Step 5: Installing two surveillance cameras

Construction Steps (Cont'd)

- Step 6: Marking sensors location and drilling holes for sensor trees



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)

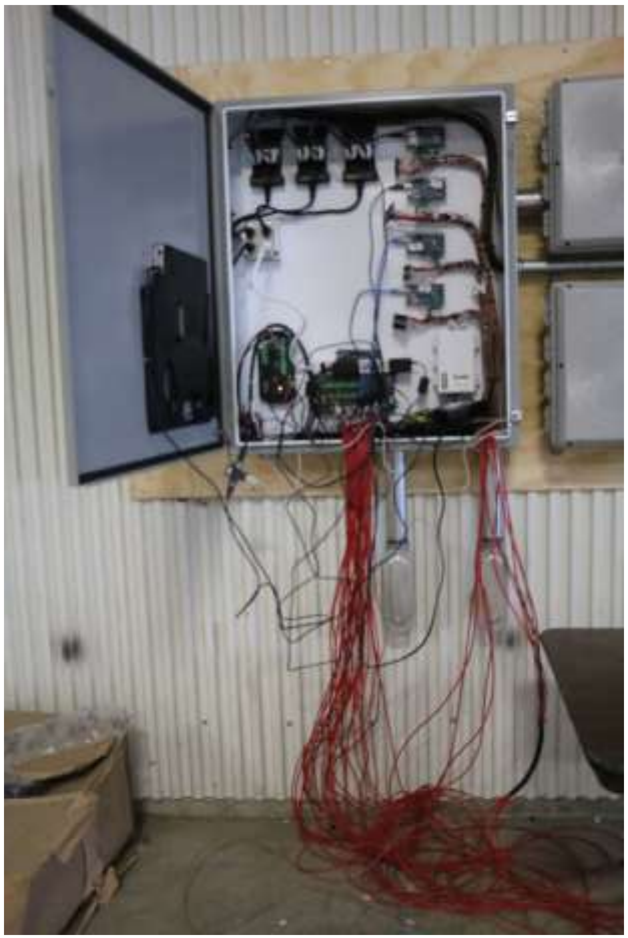
- Step 8: Placing sensors

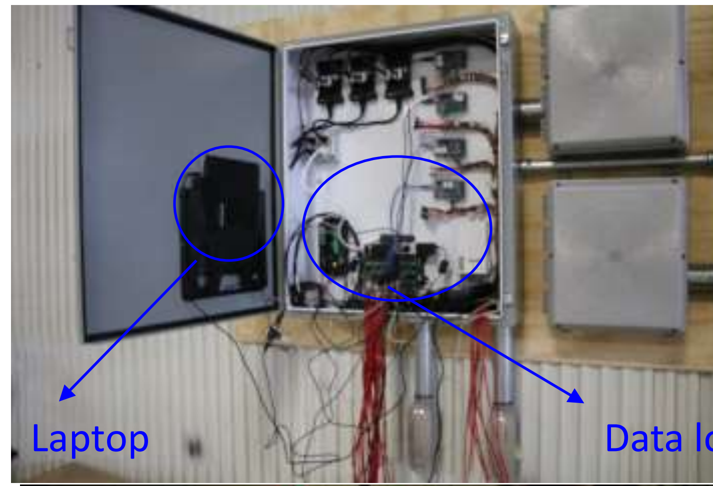
Construction Steps (Cont'd)

- Step 9: Placing the wires through PVC conduits and connected to the data logger

Construction Steps (Cont'd)

- Step 9: Placing the wires through PVC conduits and connected to the data logger (Cont'd)





Construction Steps (Cont'd)

- Step 10: Installing the power supply (contactors) and electrical sensors

Construction Steps (Cont'd)

- Step 11: Placing fiberglass rebar on top of electrodes to prevent cracking due to environmental load

Construction Steps (Cont'd)

- Step 12: Clearing and preparing the ECON slabs before paving
  - Cleaning the surface by using air-blower

Construction Steps (Cont'd)

- Step 12: Clearing and preparing the ECON slabs before paving (Cont'd)
  - Distributing the wires bundle to prevent cracking from edges

Construction Steps (Cont'd)

- 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

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Construction Steps (Cont'd)

- Step 14: Preparing and placing concrete screed

Construction Steps (Cont'd)

- Step 15: ECON paving
  - Paving time:2:30 PM, Date: 11/03/2016

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)

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)

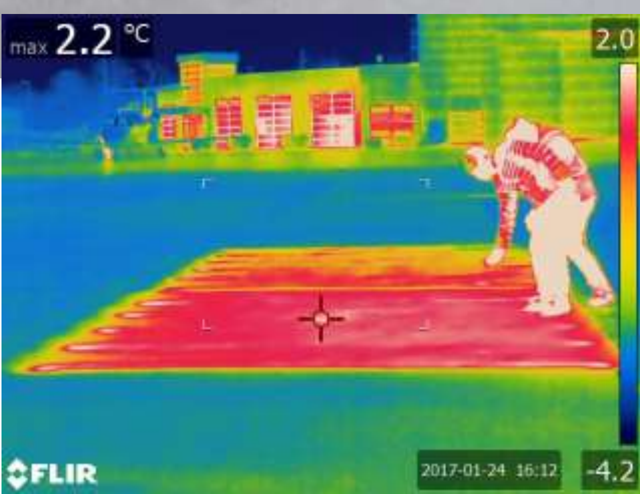
- Step 15: ECON paving (Cont'd)

Construction Steps (Cont'd)

- Step 16: Visual observation next day after ECON paving
  - No crack was observed on ECON surface

Performance Evaluation

- 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

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

Summary: Overall Benefits (Cont'd)

- 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

Summary: Overall Benefits (Cont'd)

- 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

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Thank You!
Questions & Comments?