



Green Concrete using Recycled Aggregate at Chicago O'Hare International Airport

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Airport-University Partnership

O'Hare Modernization Program

and

Center of Excellence for Airport Technology

University of Illinois



Research Topics

- Materials and Pavements
 - Sub-grade Support and Stabilization
 - Frost Problems in Pavement Components
 - Role of Potassium Acetate on ASR in Concrete
 - PCC Mix Designs
 - Reflective Cracking and Grooving Asphalt Overlays
 - Field Validation of Constructed Sub-grade and Pavement
 - Use of Warm Mix Asphalt
 - Use of Recycled Concrete Aggregate in Concrete Mix
- Airport Wildlife Safety
- Outreach Program

Coarse Aggregate Source: Quarry or Recycled?



Adoption of Recycled Aggregate

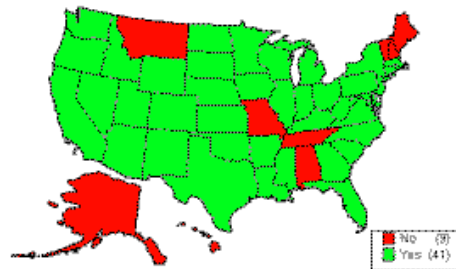


Figure 1 Recycling concrete as aggregate

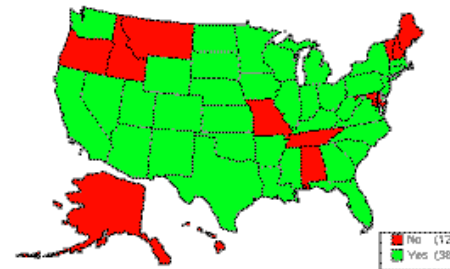


Figure 2 Base Aggregate

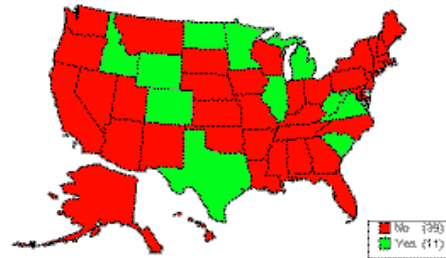


Figure 3 PCC aggregate

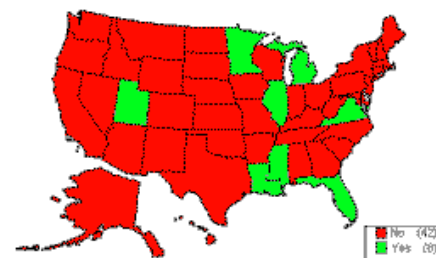


Figure 4 HMA aggregate

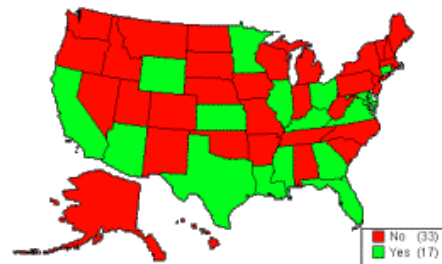


Figure 5 Miscellaneous aggregate

Recycling at ORD



Background

- Recycling rate is increasing
- But it is typically used for low-grade applications
- For high grade applications, properties must be better understood



Use of Recycled Pavements

- Low Grade Applications
 - Sub-base Material (PGE)
 - Base Material
 - Haul Roads
 - Temporary Construction
 - Staging Areas
- High Grade Applications
 - Recycled Asphalt Mixes
 - Coarse Aggregate for Portland Cement Concrete (future use)

Successes with high grade applications

- Illinois DOT I-57 (1986-87)
- Recycled concrete used for 100% of coarse aggregate in the new concrete



So why don't we use RA all the time?

Constraints:

- ✓ Lack of suitable codes, specifications, and standards
- ✓ Lack of experience

Technical Issues -- Durability, Cracking, FOD

- ✓ We need to understand the material better
 - ✓ Weak interfacial zone
 - ✓ High porosity
 - ✓ High impurity
 - ✓ Variation in quality

Current Priorities at ORD

- **Can we make a high quality PCC with recycled concrete as the course aggregate?**
- Testing program completed with CEAT
- Field testing to be performed.
- **Can we also do better with our asphalt technology?**
- Warm Mix Asphalt
- Increase Use of RAP
- Testing program programmed with CEAT
- Full scale testing

Our study at the University of Illinois

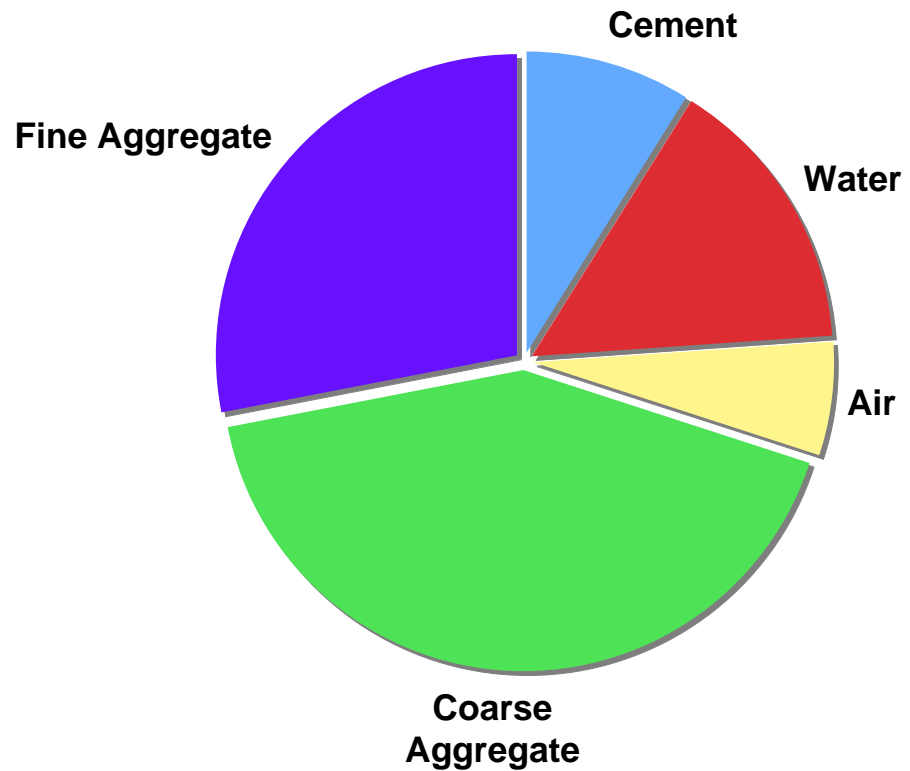
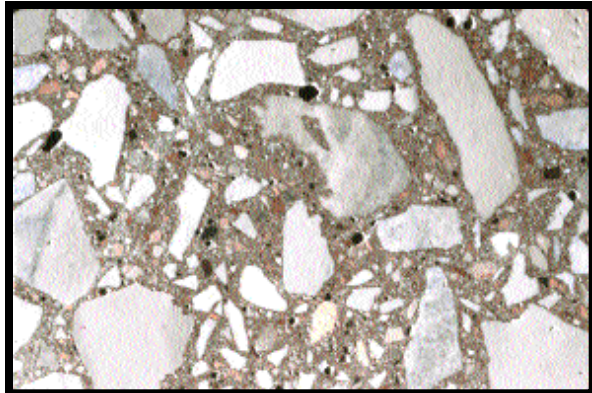
Conventional wisdom...

- Recycled aggregate is NOT the same as quarried aggregate
- Cannot simply substitute these materials
- Issues:
 - Higher absorption
 - Gradation and shape
 - Lower density

Objectives

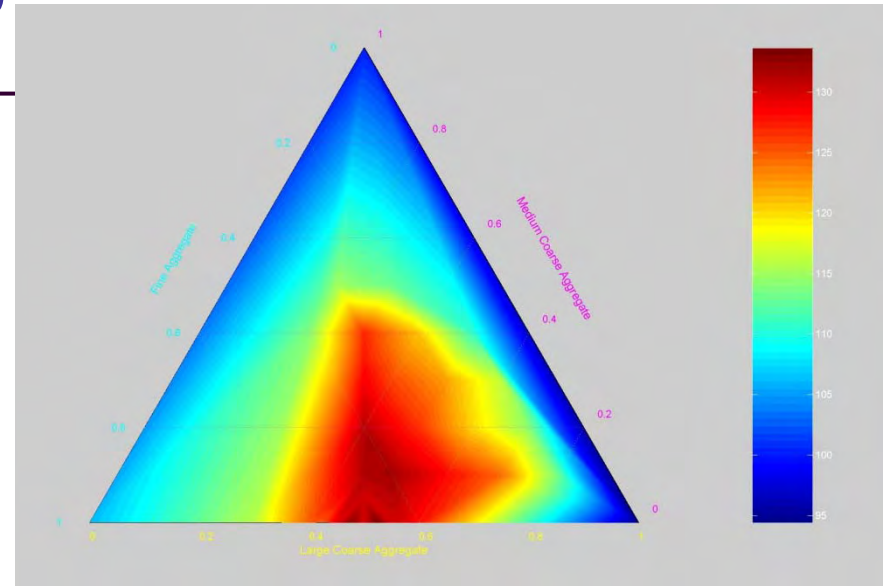
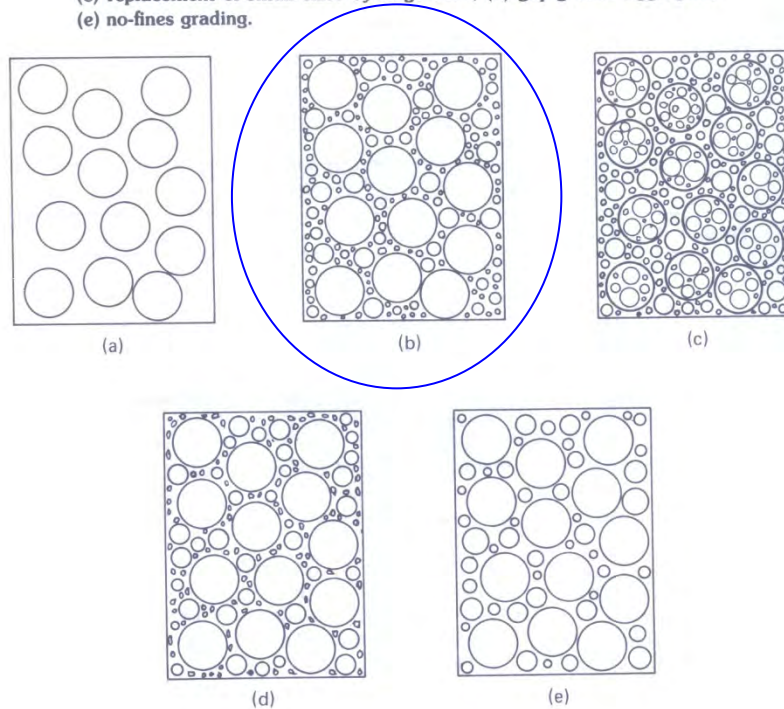
- Measure properties of recycled aggregate
- Design concrete mixtures
- Conduct field tests to refine methods
- Contribute to airport construction specs
- Improve advanced computer models of pavement systems

Concrete by volume



Particle Packing

Figure 6.2 Schematic representations of aggregate gradations in an assembly of aggregate particles: (a) uniform size; (b) continuous grading; (c) replacement of small sizes by large sizes; (d) gap-graded aggregate; (e) no-fines grading.



- Continuous grading reduces void volume
- Mathematical models can predict max density from particle sizes

Mixture Procedure (Two-Stage Mixing Approach)



Recycled coarse + cementing material

→ mix
1 min



50% water

→ mix
1 min



Virgin coarse + sand + 50% water

→ mix
2 min



Control concrete (VAC) was mixed following the commonly used mixing procedure

Summary

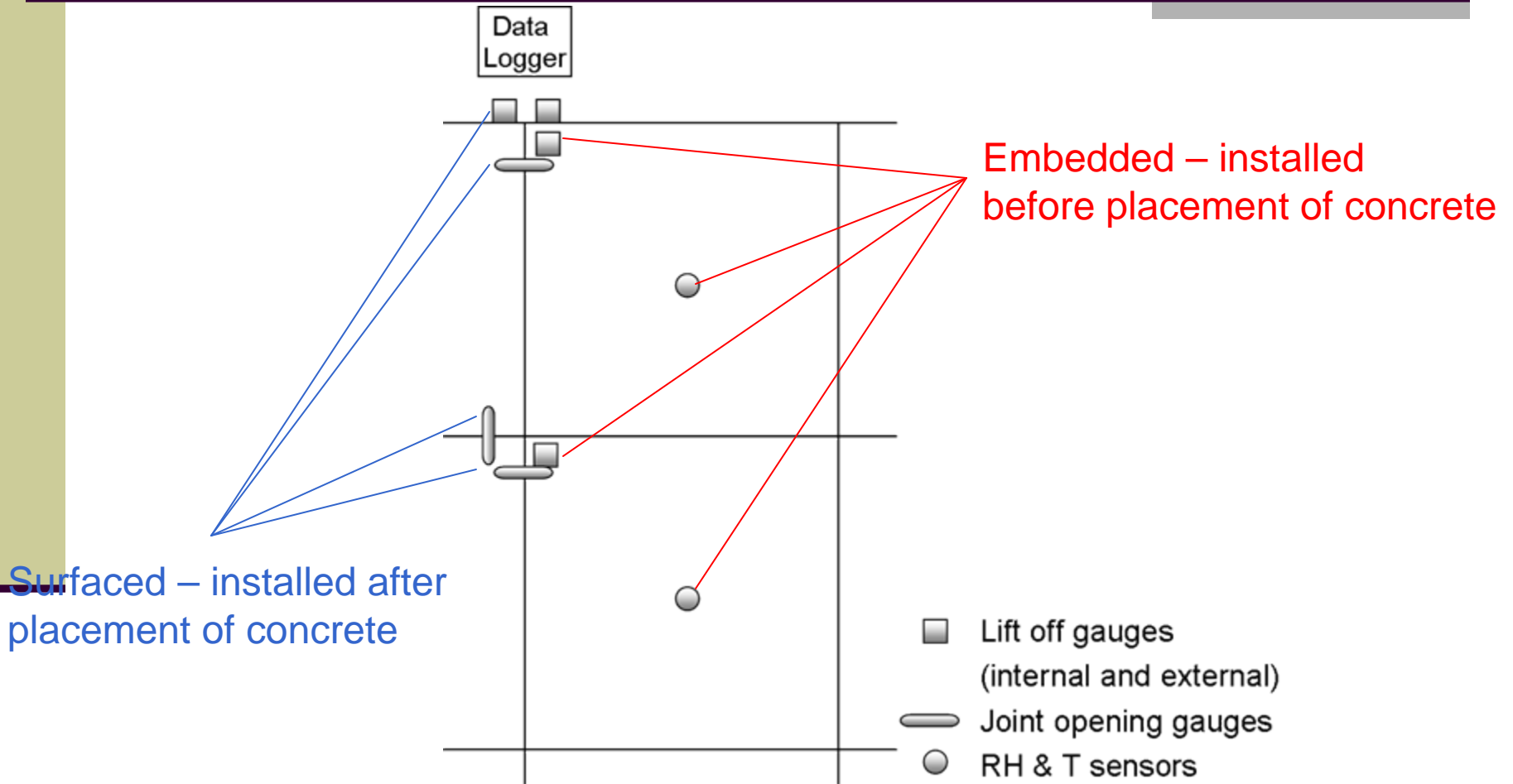
(using Two Stage Mixing Approach)

- ✓ Similar or higher compressive strength
- ✓ Similar shrinkage to VAC at early ages
- ✓ Reduced bleeding and segregation
- ✓ Similar concrete workability
- ✓ ***...yes, we can make concrete that performs!***

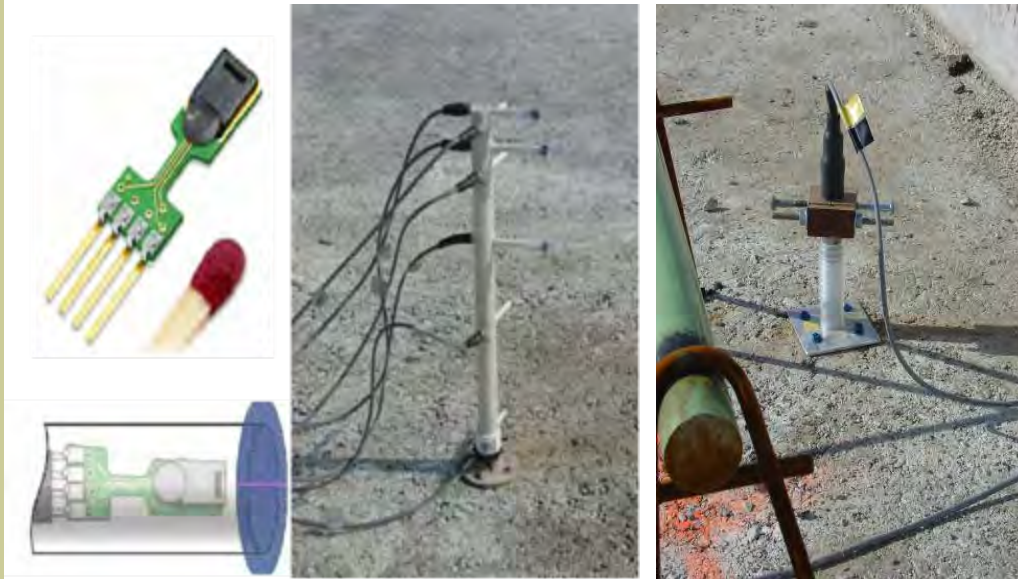
Field testing at ORD



Sensor layout



Sensors



Embedded



Surface
mounted

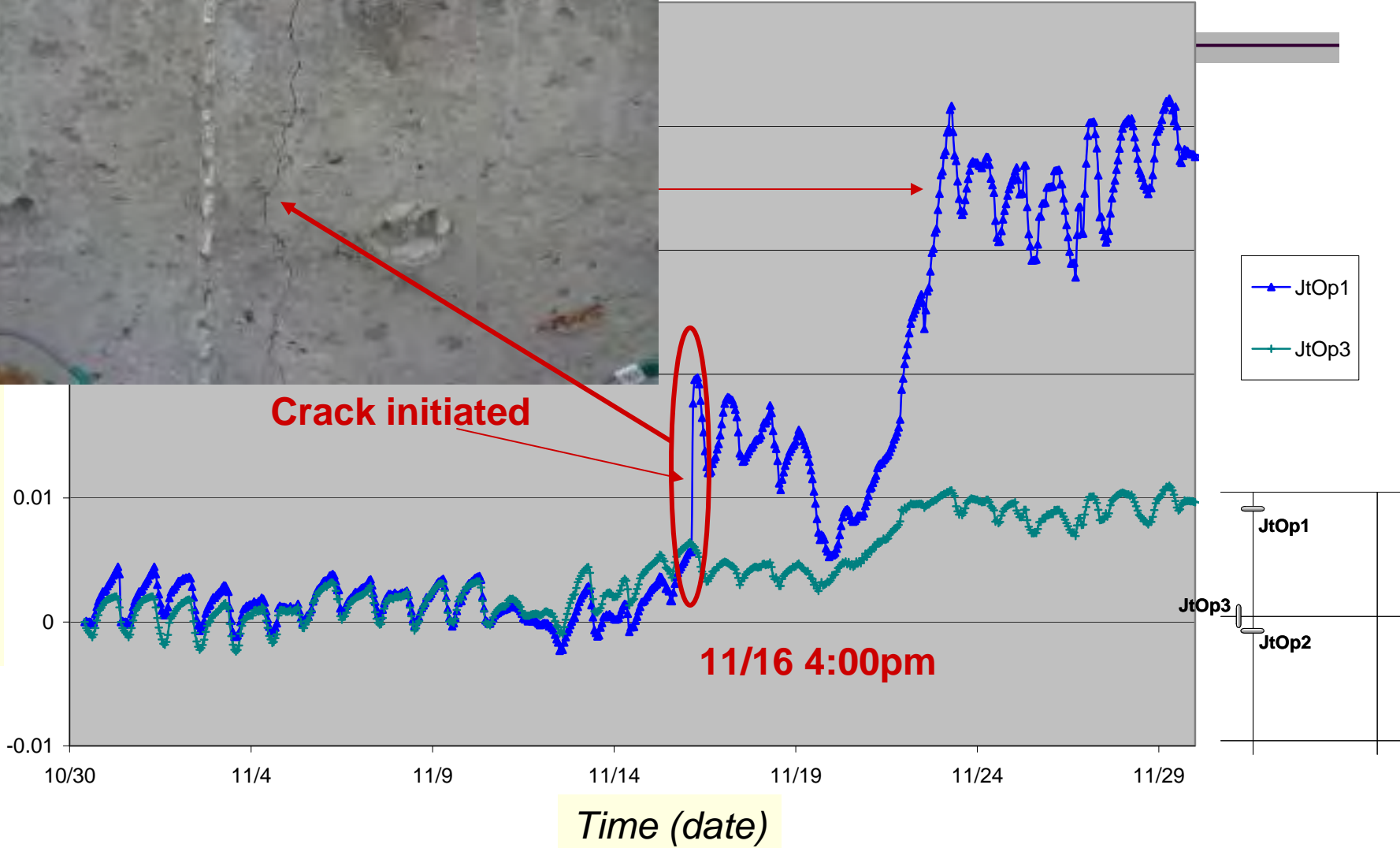
Data collection & solar power



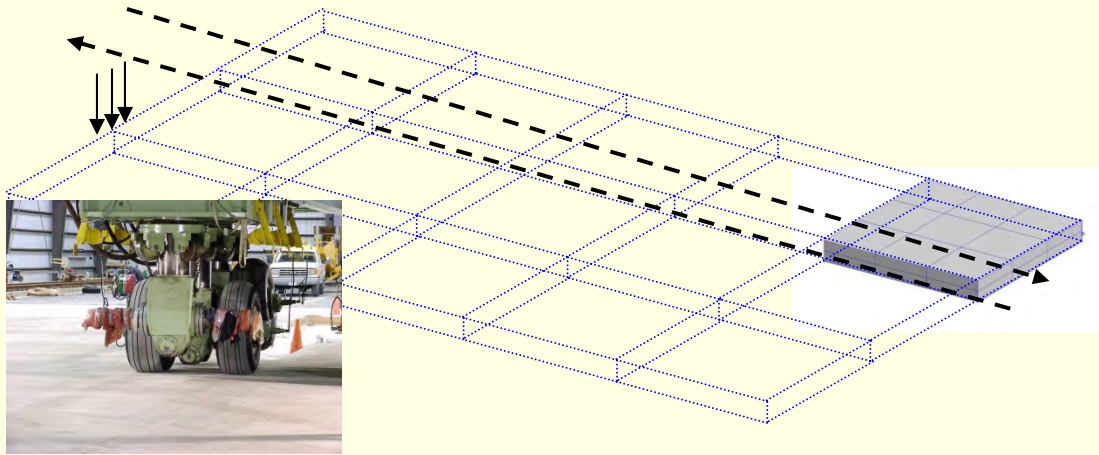


crack
opening

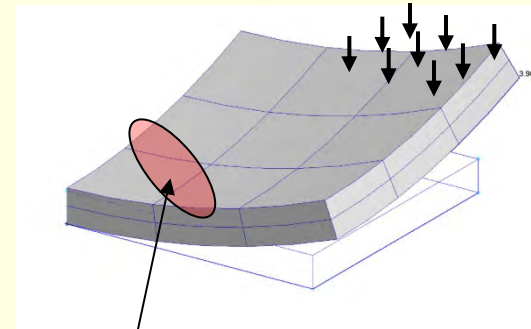
Joint Opening Δ



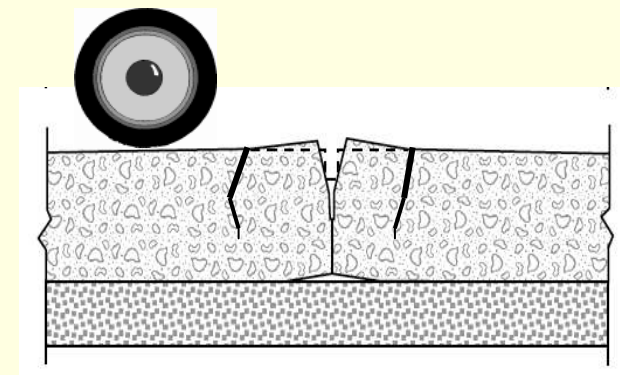
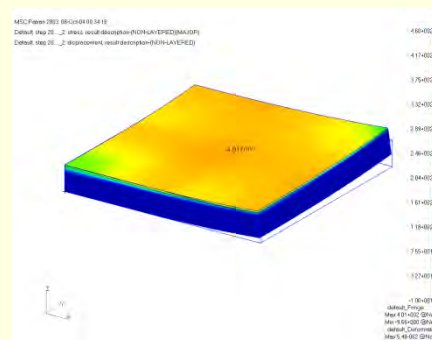
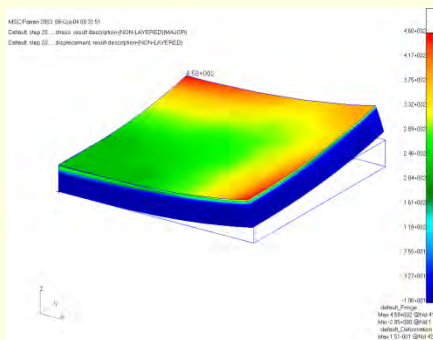
Computer modeling



SLAB CURLING P



HIGH STRESS



New tests at ORD feature Recycled Aggregate Concrete





Imagery Date: Oct 11, 2007

© 2009 Tele Atlas
41°58'26.75" N 87°54'19.99" W

Eye alt 416 ft

Airport-University Partnerships

- *Research informs decision-making*
- *Good decisions lead to better performance and lower costs*
- *Opportunity for technology transfer*
- *Opportunity to develop new talent*