State-of-the-Art of Monitoring and Health Assessment of Critical Infrastructure

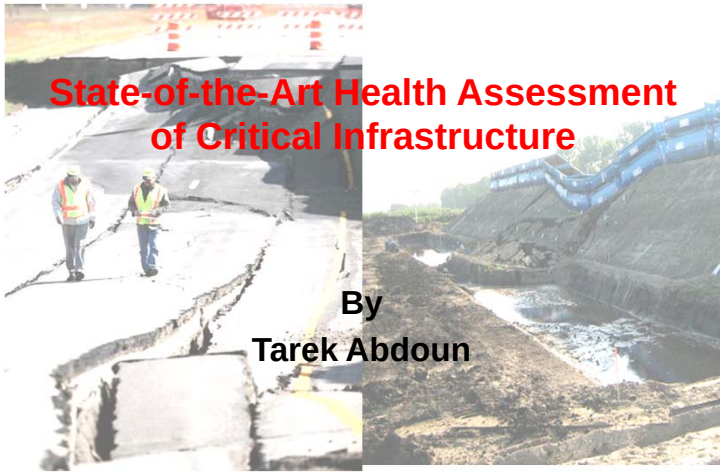
Tarek Abdoun

Abstract:

The evaluation, health monitoring and response prediction of soil and soil-structure systems during construction and due to extreme hazard conditions are on the verge of a significant paradigm shift. New and less expensive sensing technologies have enabled the development of innovative instrumentation and advanced interactive modeling tools. These tools, combined with recent advances in information technology including Satellite imagery, wireless sensor networking and visualization, promise significant improvements in real-time monitoring of urban construction, sensor-assisted design and early warning of impending failure. The presentation will focus on a newly developed wireless *Shape-Acceleration Array* (SAA) sensor that measures multi-dimensional acceleration and deformation profiles, as well as health assessment framework that provides a comprehensive multi-scale monitoring and analysis for critical infrastructure. This framework relies on long-term continuous monitoring techniques that are minimally-intrusive, and include satellite-based interferometric synthetic aperture radar (InSAR) measurements. The planned system would provide a long-term, continuous assessment of the health of soil-structure systems, allowing stake holders to prioritize repairs and rehabilitation efforts and assess the effectiveness of those efforts before a serious failure.

Presenter Bio: Professor Tarek Abdoun is the Associate Dean of Research for School of Engineering, Rensselaer Polytechnic Institute (RPI) and the Technical Director of the National Science Foundation (NSF) Network for Earthquake Engineering Simulation (NEES) Facility at RPI. A graduate of Cairo University, Professor Abdoun obtained his MSc and PhD from RPI. He is a member of more than 10 professional societies and organizations and on editorial boards of several top journals. Professor Abdoun is the recipient of several prestigious awards for outstanding research contributions. These awards include: the American Society of Civil Engineers (ASCE) 2009 ***"Walter L. Huber Civil Engineering Research Prize"***, the US Army (2007) "***Commander's Award for Public Service"*** with accompanying medal, ***Shamsher Prakash International Research Award*** for young engineers (2007), and ***Casimir Gzowski Medal*** for best journal paper for 2004.

Prof. Abdoun's technical research interests are: Modeling of Geotechnical and Geoenvironmental Systems, 3D Advanced Field Sensors, Centrifuge & Full-scale Testing, Soil-Structure Interaction, Soil Dynamics and Earthquake Engineering, Modeling of Blast Loading & Hurricane Loading, Soil Remediation, Wireless Data Acquisition Systems, 3D Data Viewer and Visualization, on which he has more than 130 research publications, many conference and keynote presentations, research reports, magazine articles and field investigation reports.



State-of-the-Art Health Assessment of Critical Infrastructure

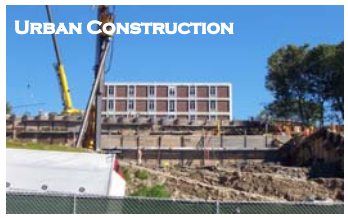
By

Tarek Abdoun

Presentation Outline

- Introduction
- Wireless Real-Time Monitoring SAA Sensor
  - Static Applications
  - Dynamic Applications
  - Structure Systems
- Sensor Aided Real-time Health Assessment

Motivation



New Orleans Flooding

Major flooding east of Metairie Outfall Canal (east of Causeway), south to MS River. Areas west, the Riverwalk, and areas due north of MS River appeared dry.

Bangkok Flooding

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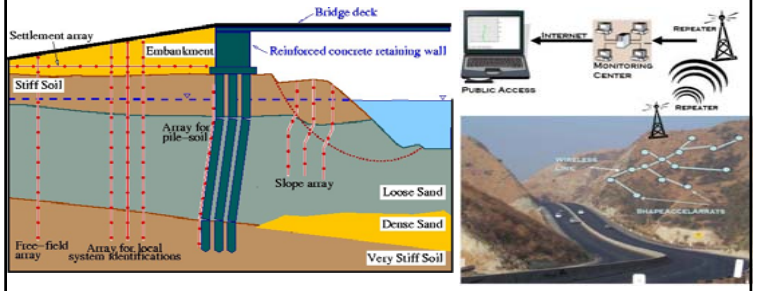
Objectives



Vision of installed shape-acceleration arrays (SAA) in an active soil-Structure system

Wireless network for real time monitoring of Soil Systems

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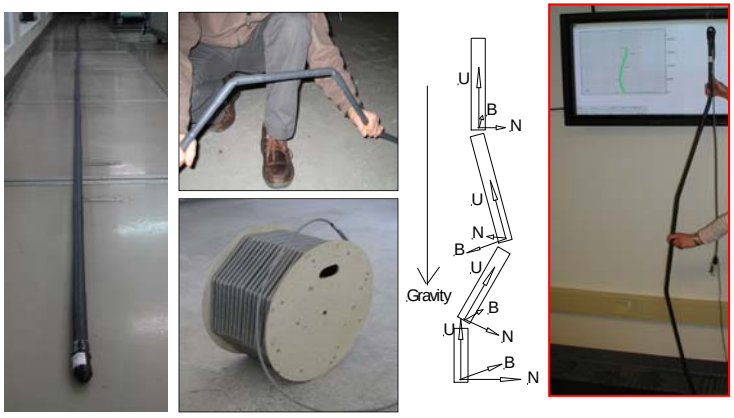
SAA Sensor Internal Setup



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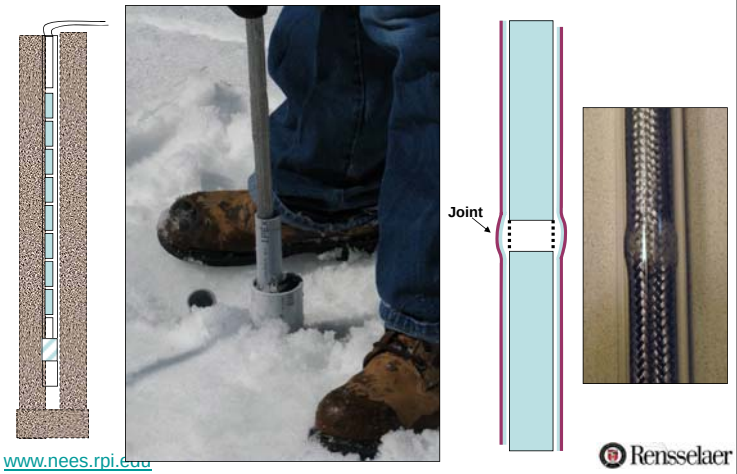
Installation Method – Small Casing



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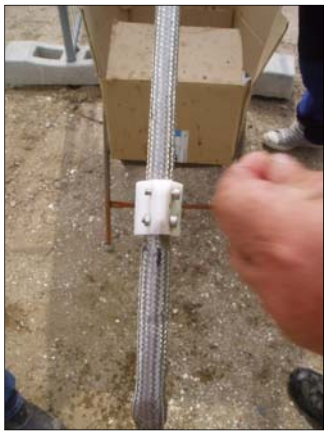
Installation Method – Large Casing



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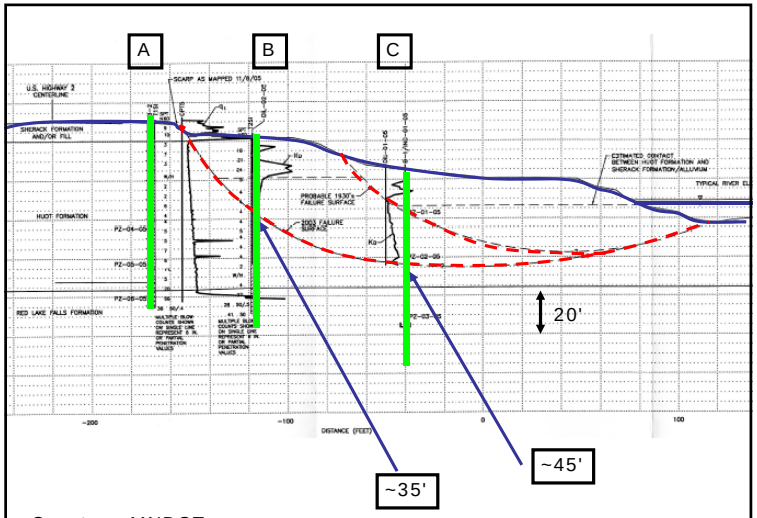
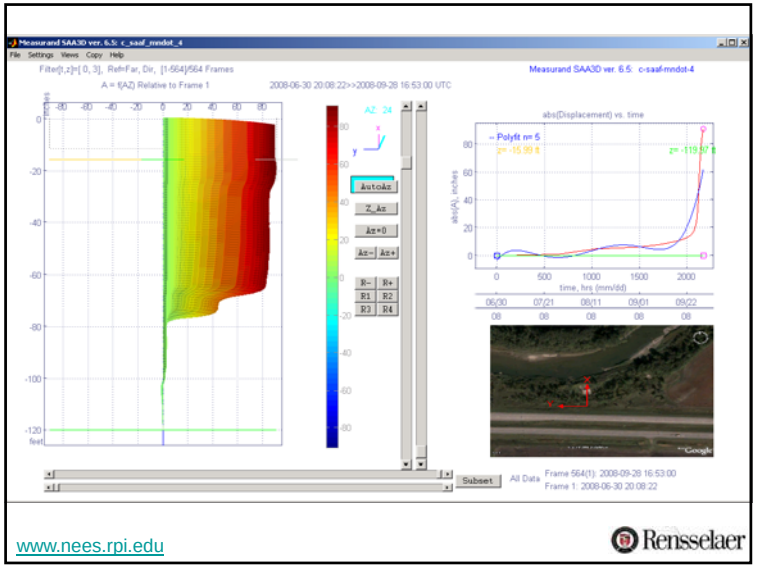
Early Warning of MN Highway Failure

Courtesy MNDOT



Courtesy MNDOT



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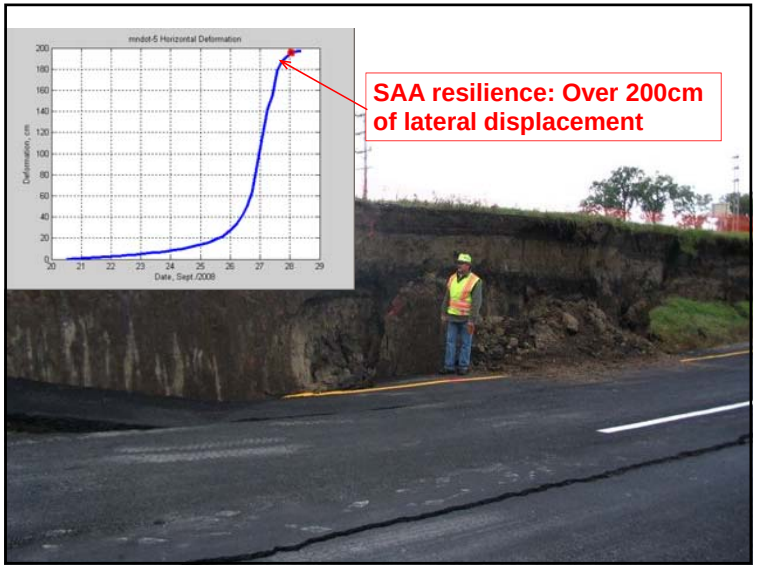

Highway Landslide

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Bridge Realignment - NYSDOT

Horizontal Installation

Geosynthetic-Reinforced Earth Wall Construction

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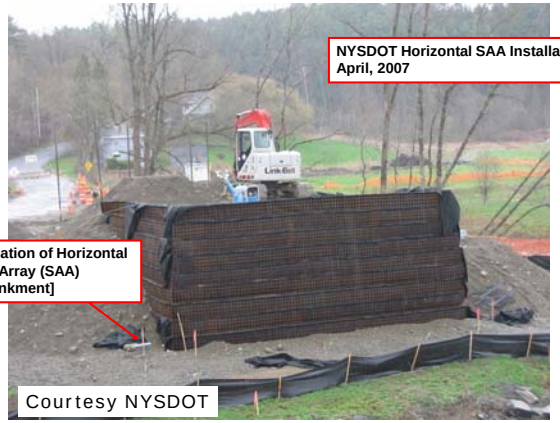
Bridge Realignment - NYSDOT



NYSDOT Horizontal SAA Installation April, 2007

[Approx. location of Horizontal ShapeAccelArray (SAA) under embankment]

Courtesy NYSDOT

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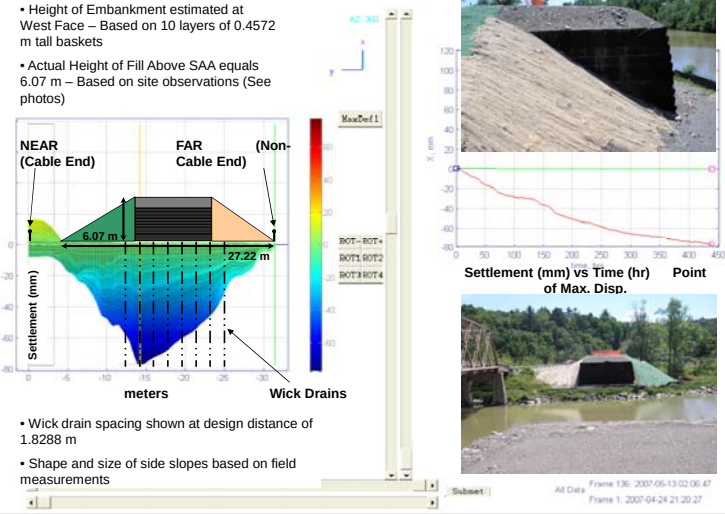
Bridge Realignment – Settlement Measurement

13 May 2007; No Time Average:
3 segment Z Average

- Height of Embankment estimated at West Face – Based on 10 layers of 0.4572 m tall baskets
- Actual Height of Fill Above SAA equals 6.07 m – Based on site observations (See photos)



- Wick drain spacing shown at design distance of 1.8288 m
- Shape and size of side slopes based on field measurements

Bridge Realignment – Settlement Measurement

26 June 2007; No Time Average:
3 segment Z Average

- Height of Embankment estimated at West Face – Based on 10 layers of 0.4572 m tall baskets
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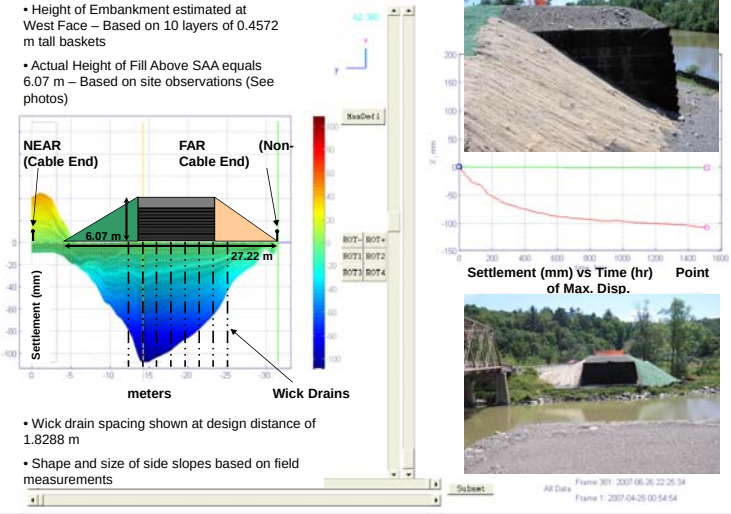

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IJKdijk Project – Piping Test
Full-Scale Testing (The Netherlands)

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Lake Marken – Peat Testing
Full-Scale Testing (The Netherlands)

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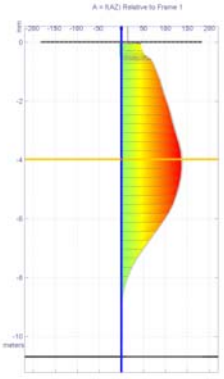
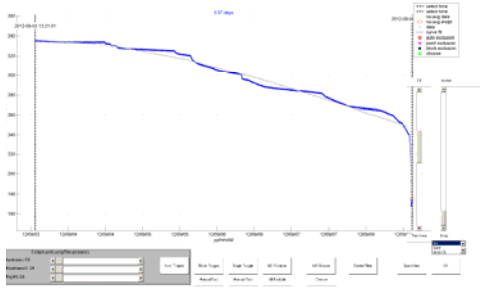
Lake Marken – Peat Testing
Full-Scale Testing (The Netherlands)



Lateral Displacement



Measured Settlement

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IJKdijk Project – Levee Monitoring
Full-Scale Testing (The Netherlands)

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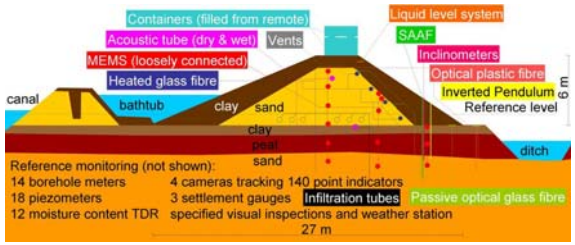
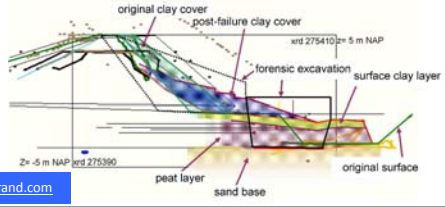
IJKdijk Project – Levee Monitoring
Full Scale Testing (The Netherlands)





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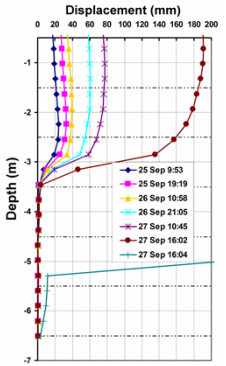
IJKdijk Project – Levee Monitoring
Full Scale Testing (The Netherlands)



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IJKdijk Project – Piping Test
Full-Scale Testing (The Netherlands)

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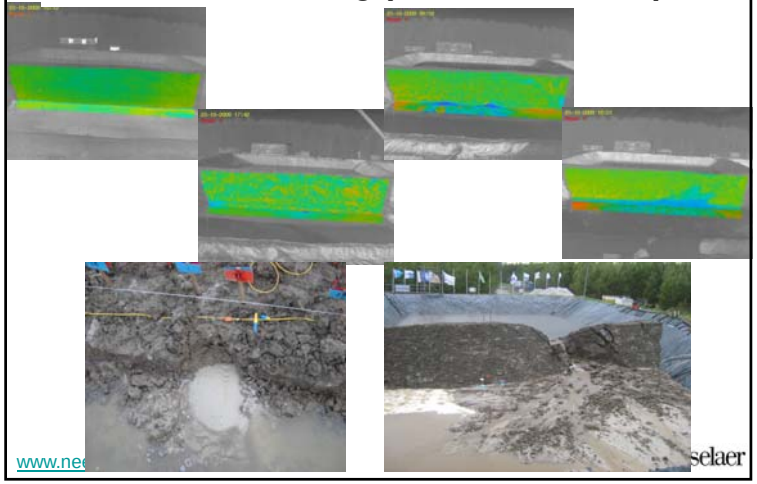
IJKdijk Project – Piping Test
Full-Scale Testing (The Netherlands)



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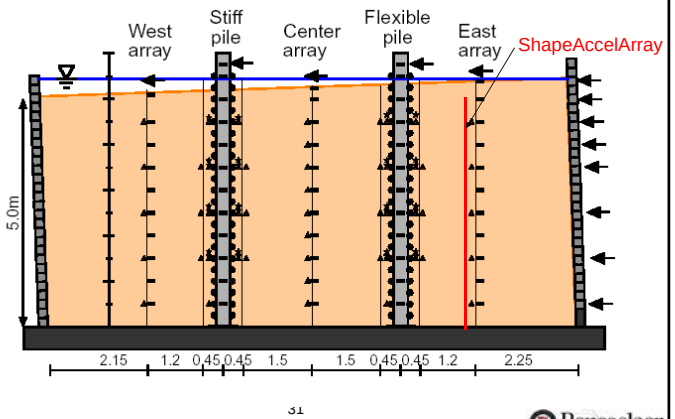
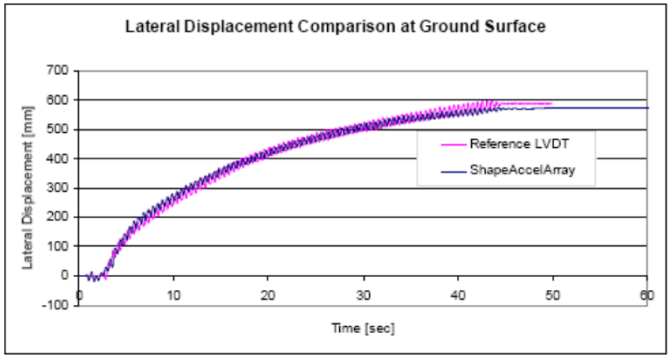
World Largest Shake Table (NIED, Japan)

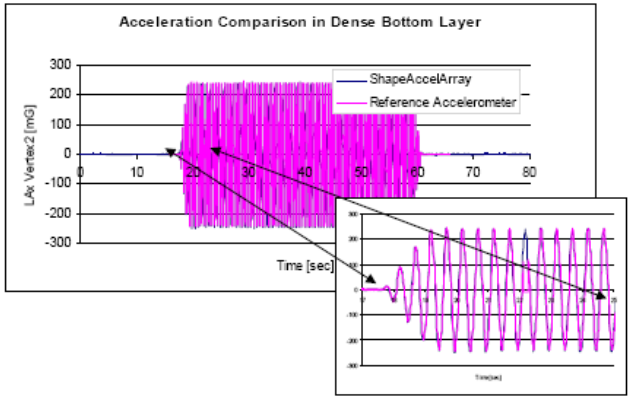
NIED Soil Model Setup



ShapeAccelArray– LVDT Preliminary Comparison



Measured Acceleration



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Investigation of a Peat bog on the Edson Sub

Site investigation and instrumentation of an embankment over a peat bog at mile 102 on the Edson subdivision

CN

University of Saskatchewan

University of Alberta

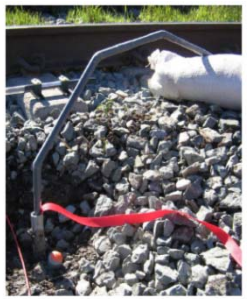
Problems at Site

↑ Moving of Ties

↑ Breaking of Ties

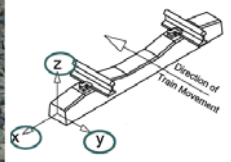
↑ Wearing of Underside

ShapeAccelArray (SAA) Install

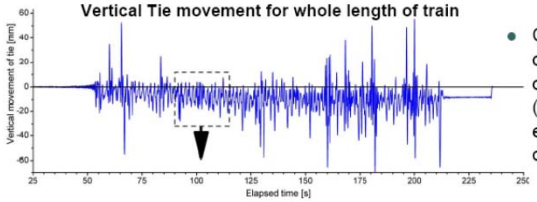


↑ 17' (of 24') down borehole. Measures movement referenced to base of BH

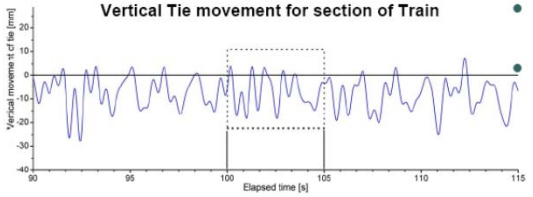
↑ Remainder of SAAR looped and clamped to tie to measure movement



Heavy Train: Vertical Tie Movement (SAA)

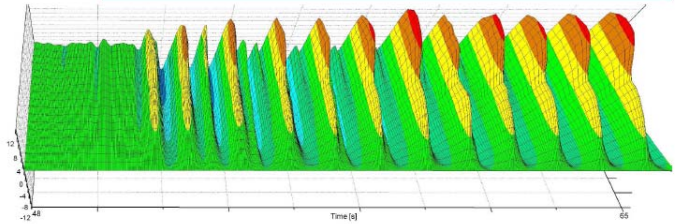


- Consolidation over the length of the train? (similar to extensometer data)



- Displacement 10-25 mm
- Deflection of tie approx. 2x extensometer data

Heavy Train: SAAR down BH 3D



- Horizontal movement of embankment and subgrade Parallel to rails to rails
- Locomotive and first few cars
- Decreasing Modulus with increasing Pore-water pressure, or possibly more complicated dynamic excitation

Urban Construction

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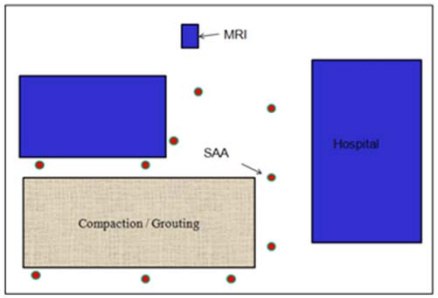
Urban Construction



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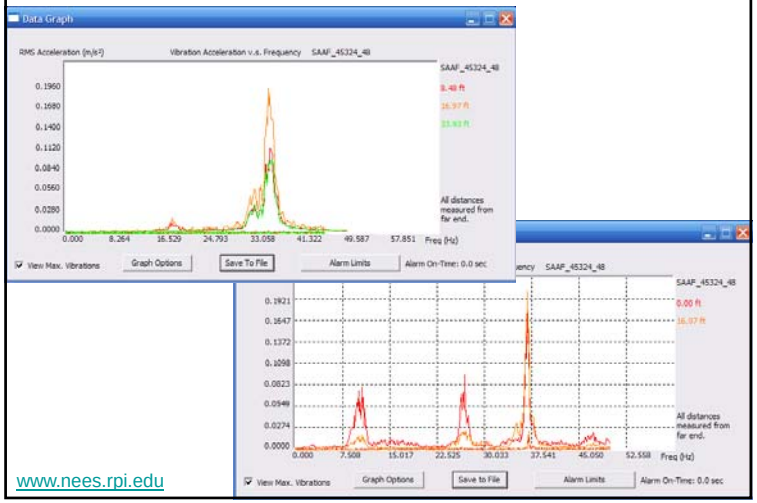
Urban Construction



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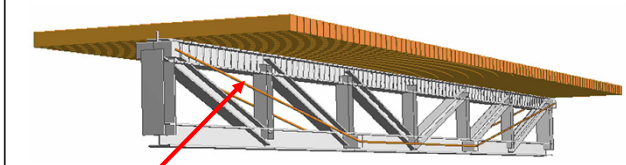
SAA - Structures Application
Bridge Deformation



2 SAAs in 10 m bridge deck, deformed by hydraulic jacks

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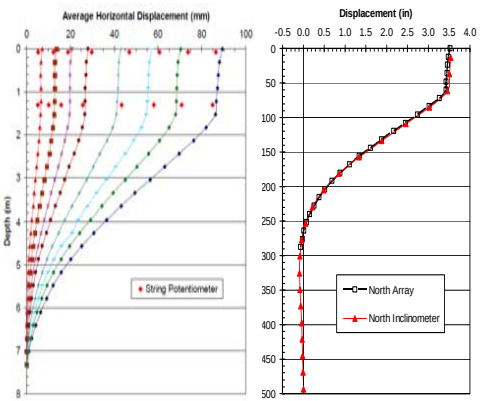
Deflection vs Depth
SAA and Inclinometer – BYU Pile Test



Courtesy Kyle Rollins, BYU

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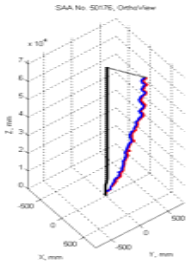
SAA - Structures Application Tunnels



Dam Project, Ontario, Canada

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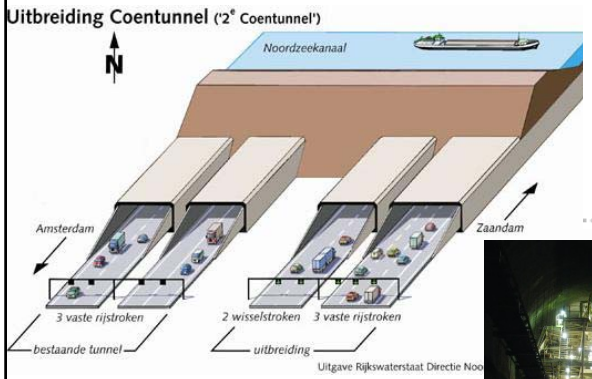
SAA - Structures Application Tunnels



Coentunnel, Netherlands

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SAA - Structures Application Tunnels

A 5 km tunnel is being built under Zurich, Switzerland. Slanted elevators (left) provide access to the new tunnel system.

Terra Monitoring (terra-monitoring.com) chose Measurand SAAs for critical settlement and grout injection monitoring work associated with this new tunnel system.

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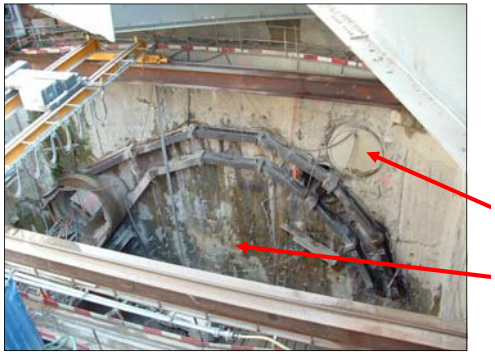
SAA - Structures Application Tunnels



The cable serves three 40 m horizontal SAAs deployed to measure subsidence over a 120 m path in a micro-tunnel forming an upper support structure for the main Zurich Train Tunnel.

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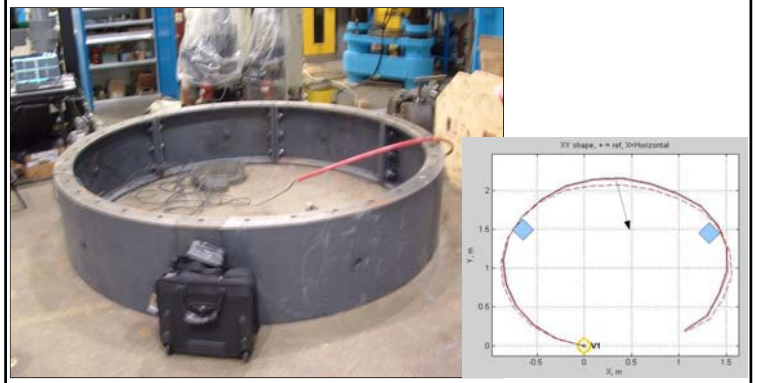
SAA - Structures Application
Tunnels



Imperial College in London, UK, study using SAA to measure convergence. An SAA is mounted to a tunnel support ring which can be deformed to evaluate SAA as a means of measuring convergence.

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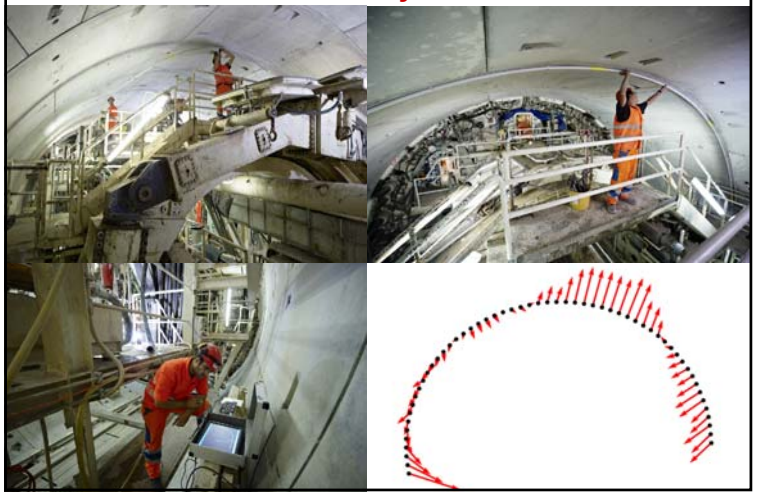
SAA - Structures Application
Tunnels: Cross-City-Link in Zurich



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Development of a Multiscale Monitoring and Health Assessment Framework for Effective Management of Levees and Flood-Control Infrastructure Systems

Joint-Venture:
Rensselaer Polytechnic Institute
(M. Zeghal, T. Abdoun and B. Yazici)
and
Geocomp (A. Marr)

Geocomp products FIELD SYSTEMS www.geocomp.com

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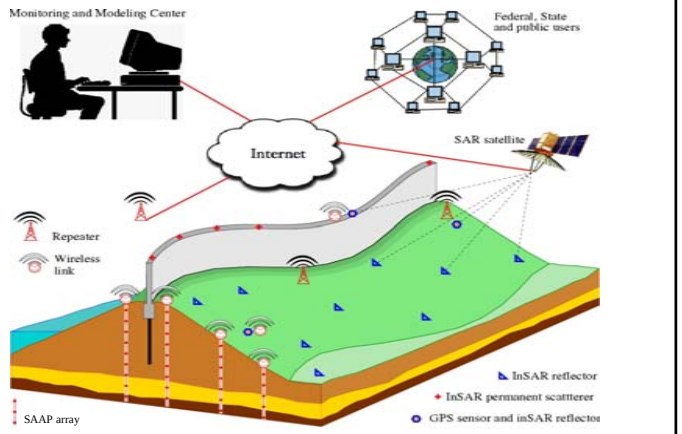
Summary: Project Overview



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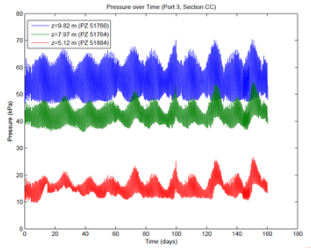
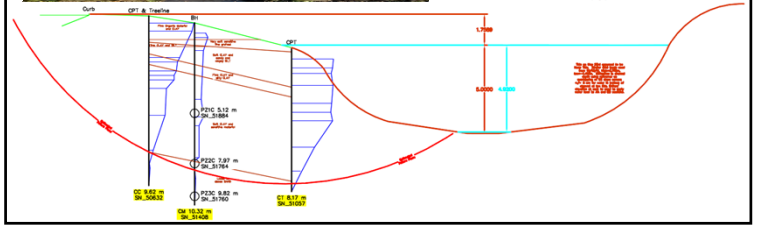
Full-Scale Levee Test

River Witham, Boston, UK

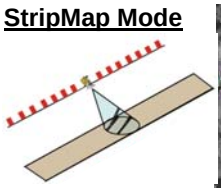
Boston, UK Field Installation



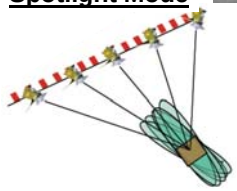


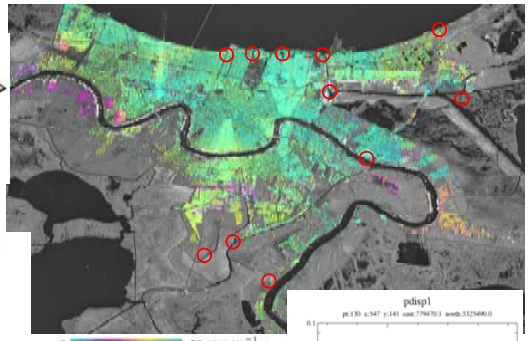
Global Monitoring: Satellite (InSAR)

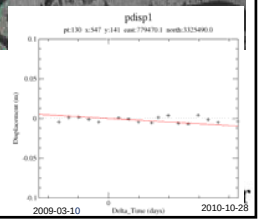
StripMap Mode



Spotlight Mode

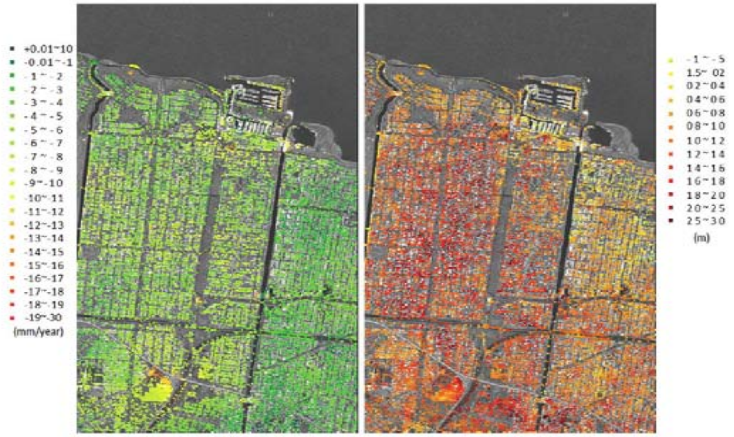






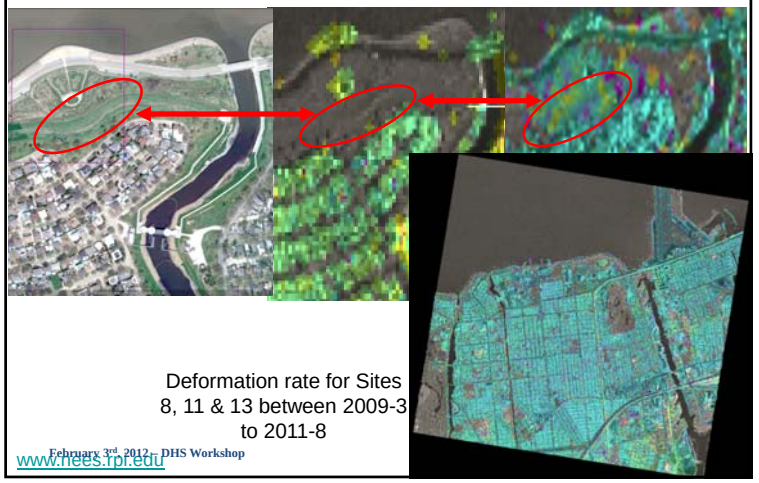
Working Mode	Resolution(meter)	Imaging Area((km)x(km))
Spotlight	1	5x10
StripMAP	3	30x50

InSAR: New Orleans



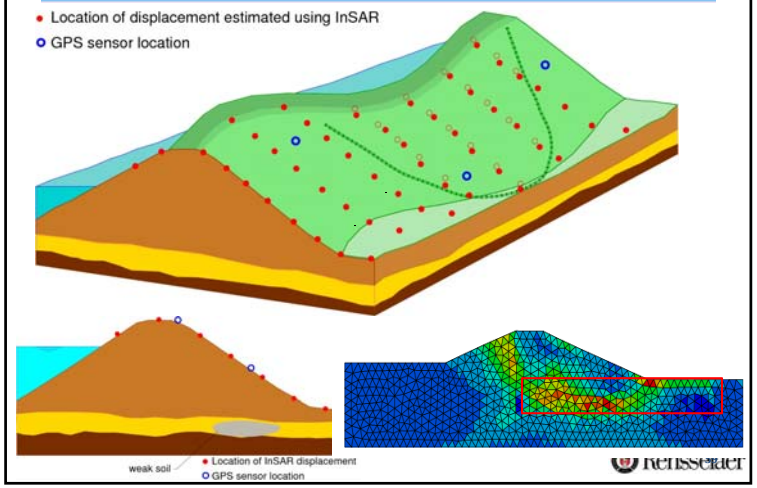
• Rate of subsidence (left) and elevation (right) in 17th St. Canal area of New Orleans between Feb. 2009 and Oct. 2010 based on 18 TerraSAR-X images.

InSAR: Enhanced Preprocessing/Coherence



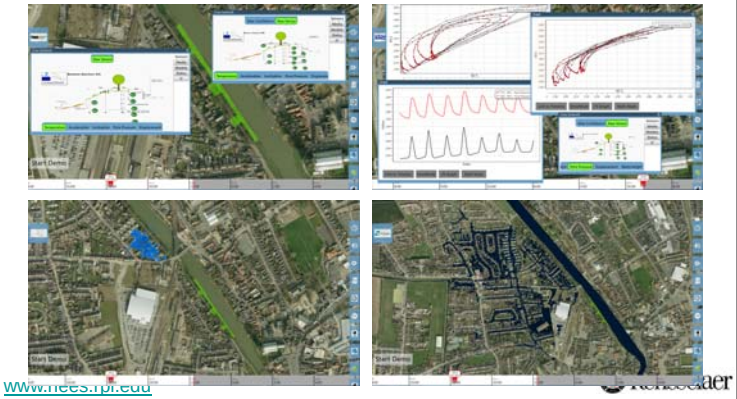
Deformation rate for Sites 8, 11 & 13 between 2009-3 to 2011-8

Health Assessment



Current Development

Develop fully integrated health assessment & visualization tools for decision making & disaster training



Current Development

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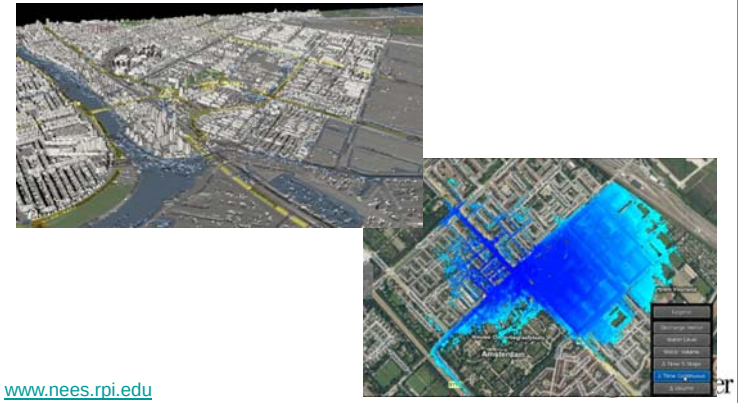

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