STRUCTURAL HEALTH MONITORING TECHNOLOGY

Richard "Lee" Floyd, PE and Peter J. Vanderzee

PRESENTATION CONTENT

- **Presentation – Part I**
  "Lee discusses SCDOT challenges, solutions employed and future plans."
- **Presentation – Part II**
  "Pete discusses need for monitoring, financial benefits, applications and best practices."
- **Presentation – Part III**
  "Lee discusses the TIDP Project and takes audience questions."

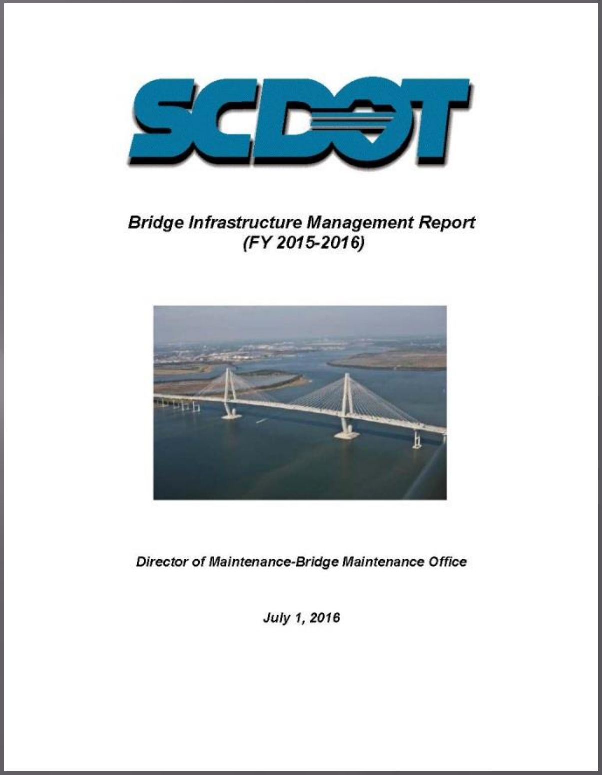
PART I – LEE FLOYD, PE
STATE BRIDGE MAINTENANCE ENGINEER
SCDOT

SCDOT CHALLENGES

- *Safety is Job 1*
- *Bridge conditions*
- *Visual and tactile*
- *Long term funding*
- *Asset management*
- *Embracing change*
- *Benefits – Cost*

RESOLVING CHALLENGES

- ***Inspection QA/QC***
- ***Acknowledging and defining issues and problems***
- ***Developing and testing options***
- ***Working with pros***
- ***Long term solutions and program***

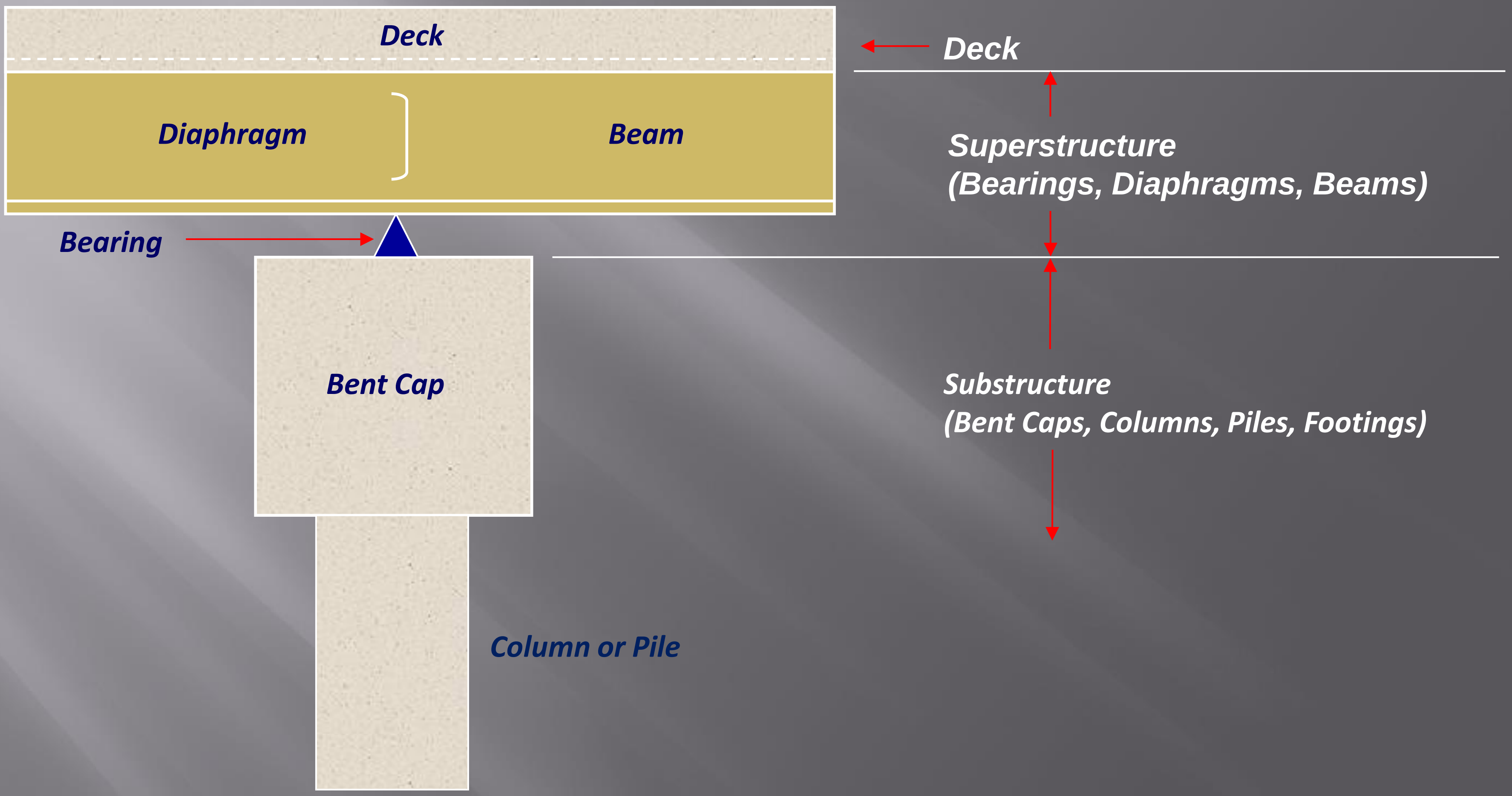

SCDOT

Bridge Infrastructure Management Report (FY 2015-2016)

Director of Maintenance-Bridge Maintenance Office

July 1, 2016

BRIDGE NOMENCLATURE



NBIS CONDITION ASSESSMENT

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION - no problems noted.
7	GOOD CONDITION - some minor problems.
6	SATISFACTORY CONDITION - structural elements show some minor deterioration.
5	FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION - advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION - loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION - out of service - beyond corrective action.

LIMITATIONS OF NBIS DATA

- ***Subjective process; variable; not that precise***
- ***Component level qualitative data vs. element and material level qualitative and quantitative data***
- ***NBIS is a safety system - not a management system***
- ***Substandard Bridge Classifications:***
  - ***Structurally Deficient – SD***
  - ***Functionally Obsolete – FO***
- ***No effective predictive analyses/algorithms***

WHAT OTHERS SAY ABOUT NBIS

- ***Visual condition ratings varied by +/- 2 states from the mean in a 2000 FHWA study (1)***
- ***"This methodology is highly subjective and produces variable results" (2)***
- ***"Visual inspection also does not capture hidden deterioration or damage" (3)***

1. *Reliability of Visual Inspection; Public Roads Magazine, March/April 2001*
2. *Condition Assessment of Highway Structures, Past, Present and Future; TR Circular E-C104*
3. *IBID*

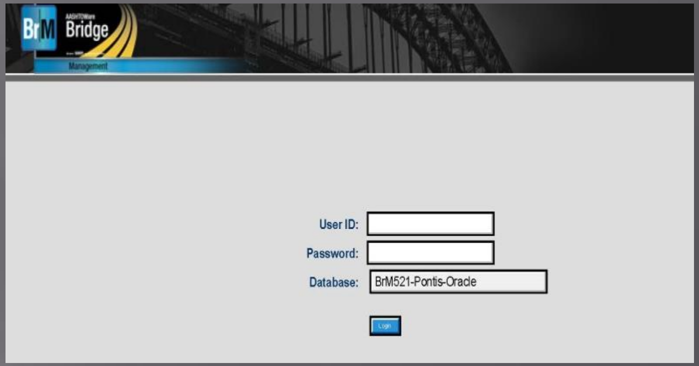
EXAMPLE OF A CONDITION STATE

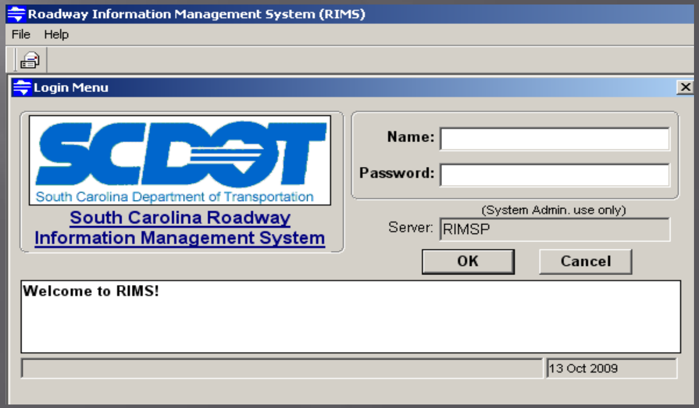
State 4:

The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.

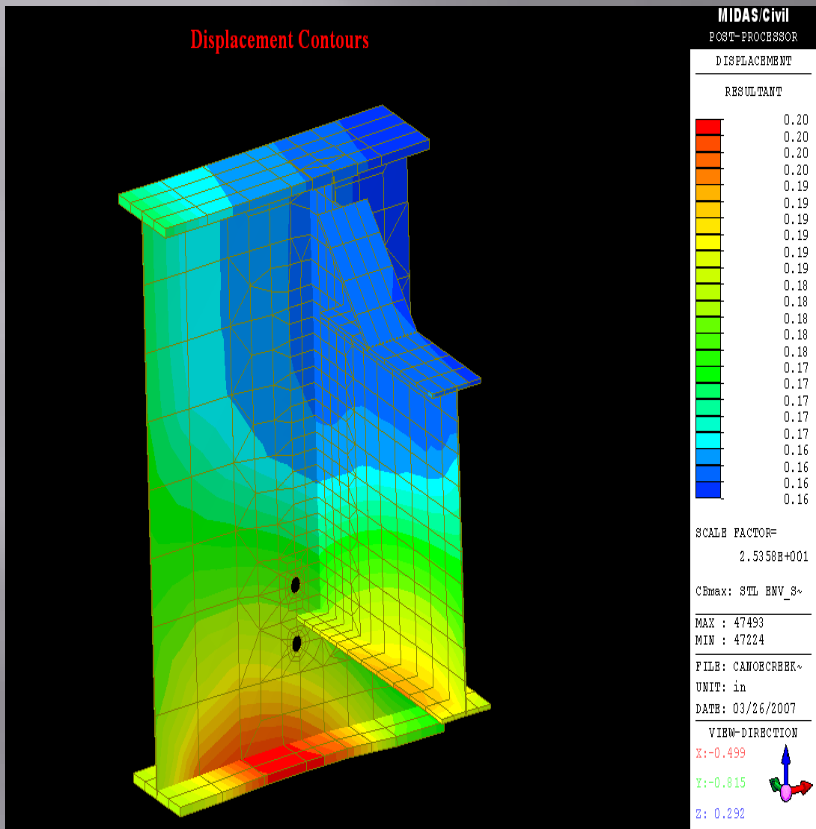
BRIDGE MANAGEMENT DATA

- ***Qualitative and quantitative issues are minimized***
- ***Quantitative and element specific data:***
  - ***Provides detailed data and reporting***
  - ***Detailed analytical modeling***
  - ***Effective predictive analyses***

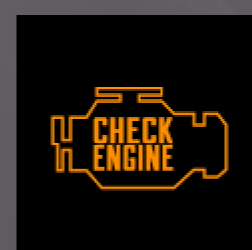




INTEGRATING TECHNOLOGY WITH NBIS

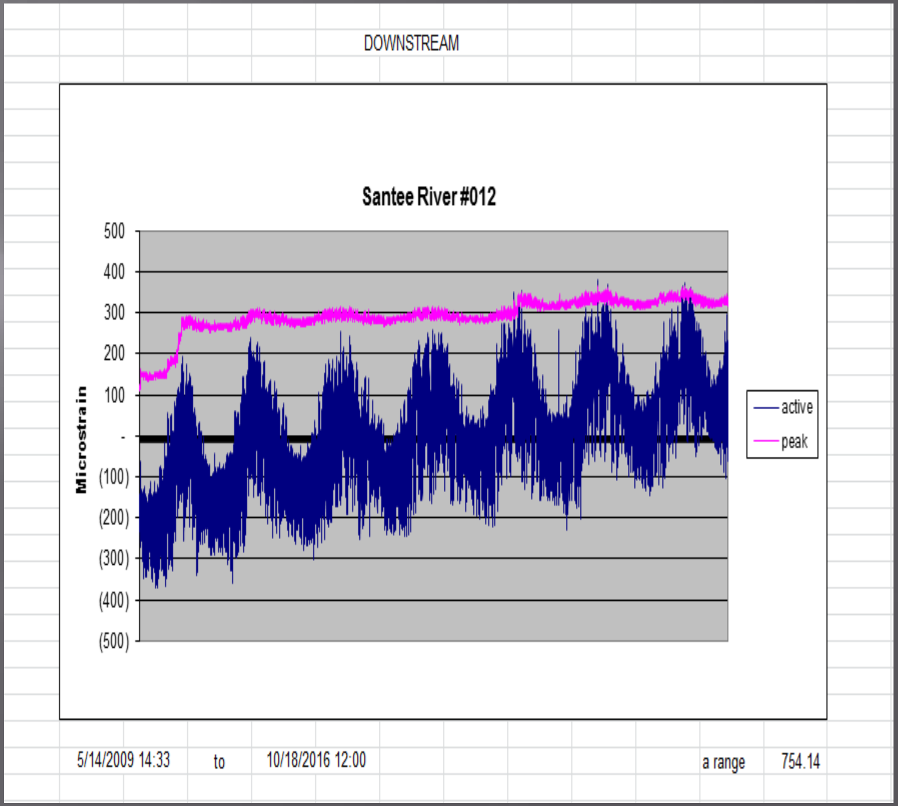


- ❑ *Precise assessment of condition*
- ❑ *Strain, especially peak*
- ❑ *Temperature*
- ❑ *Known defects*
- ❑ *Information via Internet*
- ❑ *System reliability*
- ❑ *Out-of-tolerance alerts*



BENEFITS OF MONITORING TECHNOLOGY

- ***Enhanced safety***
- ***Prevention/removal of unnecessary load postings***
- ***Safe deferrals of rehabilitation & replacement actions***
- ***Rehabilitation actions versus replacement***
- ***Return on investment***



FUTURE SCDOT MONITORING PROGRAM

- *Increased use of monitoring on other long span bridges*
- *Increased load testing of short span bridges*
- *Integrated analytics*

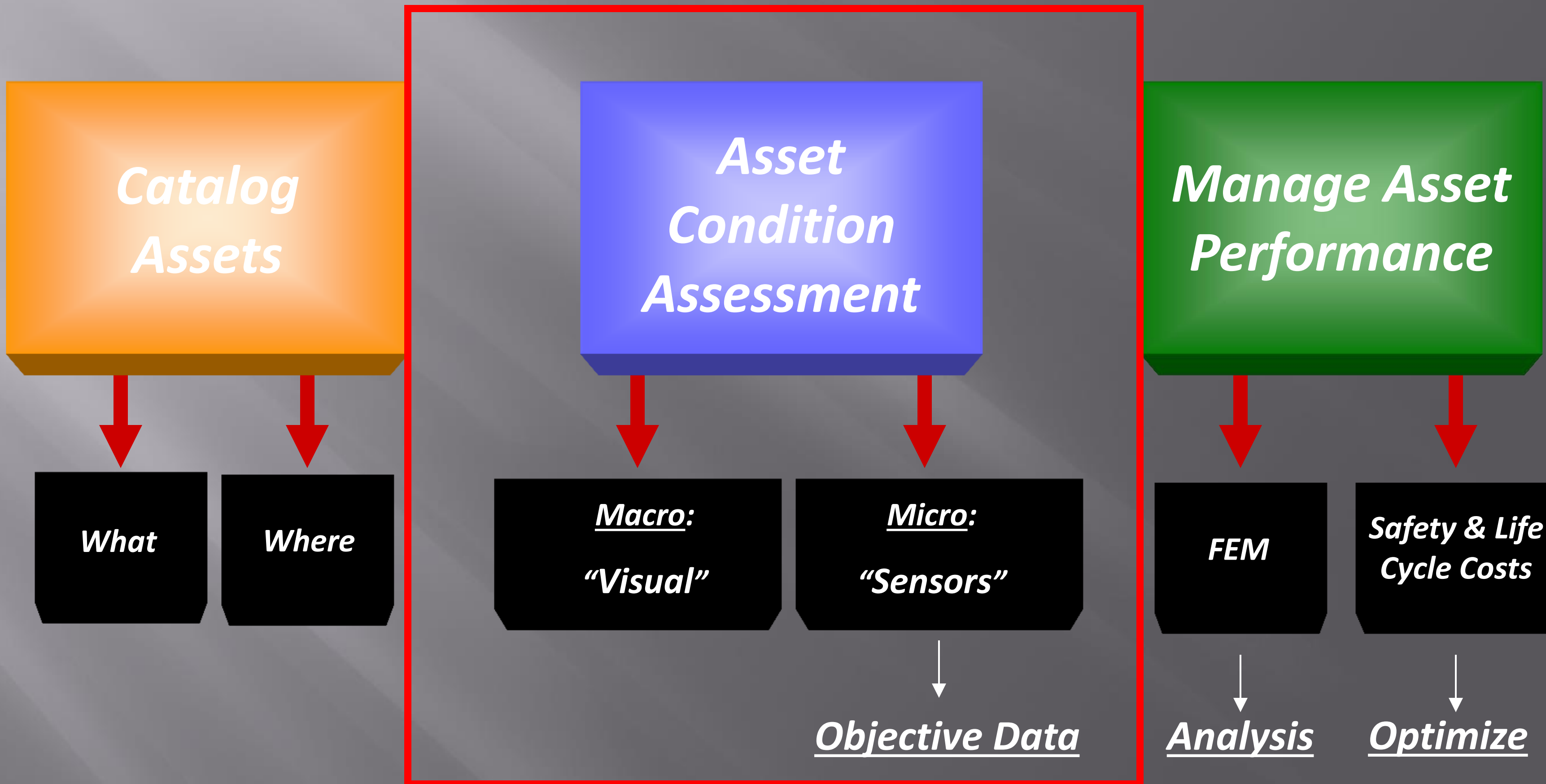
SCDOT Joint Research Program for Highway Bridge Assessment and Rating
Keeping Communities Connected
CLEMSON UNIVERSITY

I-526 WB @ Wando River

- ***Precast Concrete PT Segmental Box***
- ***Ruptured PT Tendon***
- ***Calculations indicated tension (200 psi +/-) in the extreme fiber of concrete***
- ***Strain sensors indicated that we were still slightly in compression and crack sensors showed no movement***

PART II – PETER J. VANDERZEE
PRESIDENT/CEO
LIFESPAN TECHNOLOGIES

MODERN ASSET MANAGEMENT



MANAGING WITH UNCERTAINTY

- ***Structures in good to very good condition should be <u>optimally maintained</u>***
- ***Structures in very poor to extreme condition must be replaced <u>or carefully monitored</u>***
- ***Structures in Unknown Zone should be objectively <u>assessed and managed accordingly</u>***

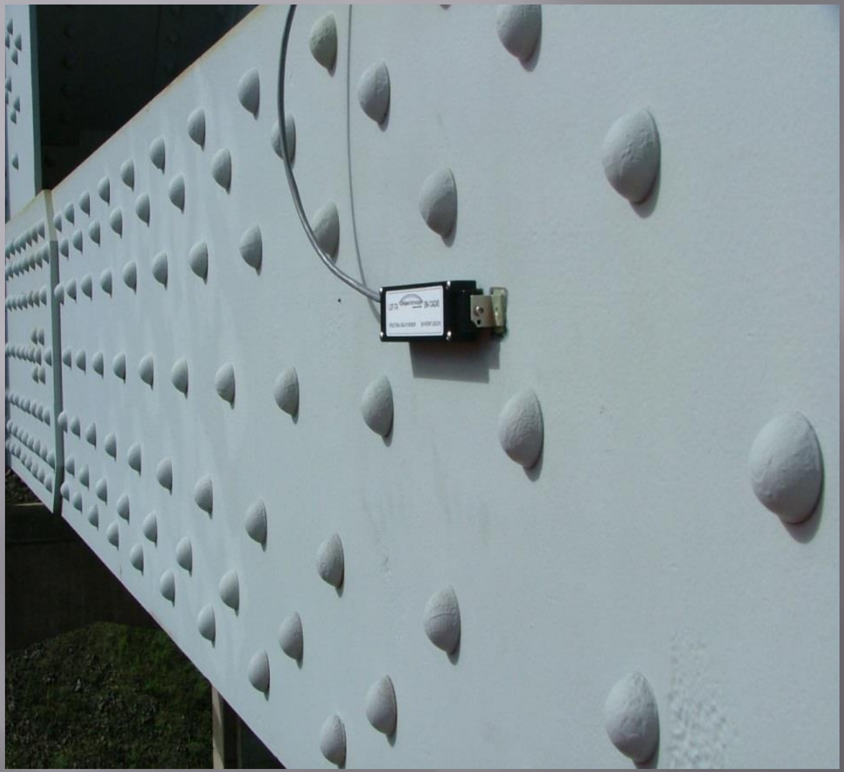
WHEN TO USE MONITORING

- ***Before a major rehabilitation project***
- ***Before a major replacement project***
- ***Known defects, e.g. cracks, out-of-plane bending, bearings***
- ***Long detours from load posting***

MONITORING TECHNOLOGY TRUISMS

- *Data intensity is over-rated*
- *Sensor accuracy is over-rated*
- *Monitoring periods are under-rated*
- *Use sensors that fit the need*
- *Minimize sensors to start; allow for progressive diagnostics*
- *Professional installation is essential*
- *A professionally managed data center is crucial*
- ***Ensure a return on investment.***

THE PEAKSTRAIN™ SENSOR



- ***Multi-use applications for known defects and structural members:***
  - ***Displacement/strain***
  - ***Crack width/propagation***
  - ***Out-of-plane bending***
  - ***Bearings***
- ***Dual channel design***
- ***Developed for long-term monitoring – <u>years:</u>***
  - ***Tension or compression***
  - ***Displacements up to 95 mm***
  - ***Peak strain without power***
- ***Data generated translates to <u>actionable</u> information***

BENEFIT-COST FROM MONITORING

- *$3 Million dollar bridge costs $150K/yr. (interest):*
  - *If no action required: payback in ~1 yr.*
  - *If rehab vs. replacement: payback in ~1-2 yrs.*
- *$10 Million dollar bridge costs $500K/yr. (interest):*
  - *If no action required: payback in ~6 months*
  - *If rehab vs. replacement: payback in ~9-12 months*
- *$50 Million dollar bridge costs $2.5M/yr. (interest):*
  - *If no action required: payback in ~2 months*
  - *If rehab vs. replacement: payback in ~3-4 months*

Note 1: Rehab assumed 25% of replacement cost

Note 2: Probabilities should be factored into calculations

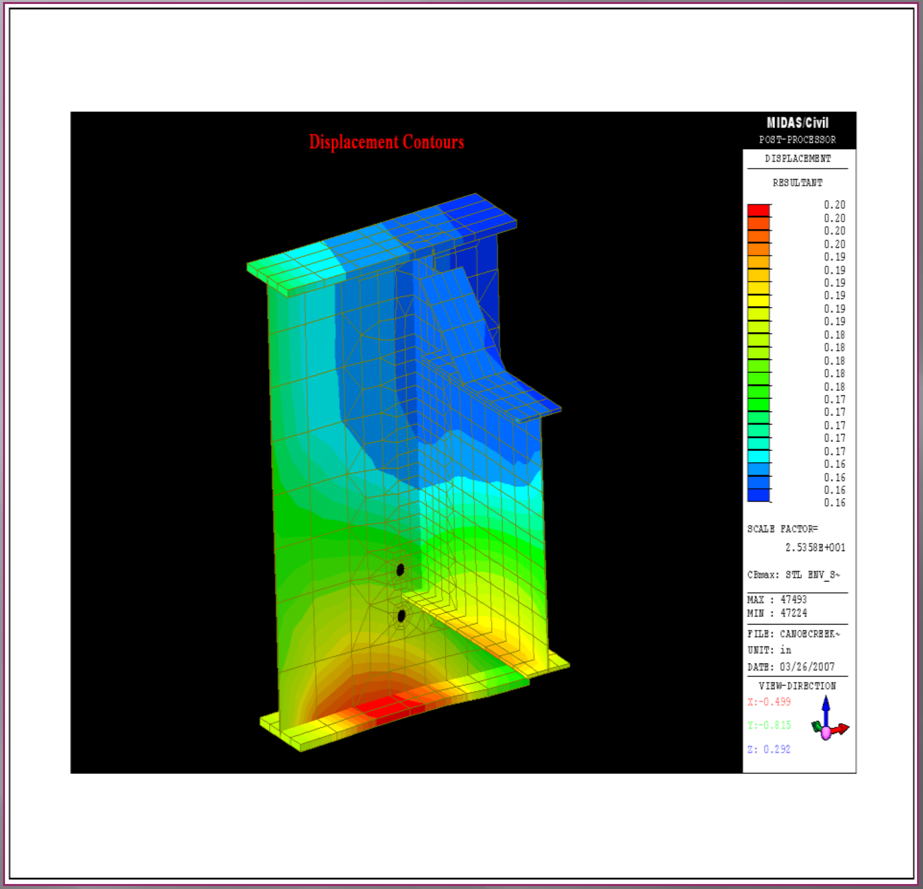
SAFELY DEFERRING REPAIR

- ***Problem: Is the third party (NBIS report) recommended repair program necessary?***
- ***Customer: Pennsylvania Turnpike***
- ***Objectives:***
  - ***Monitor key tensile and compressive strains***
  - ***Calibrate FE model to analyze current condition and repair efficacy***
- ***Results:***
  - ***Recommended safe deferral of $875,000 repair program***
  - ***Recommended bearing replacement***
- ***Conclusion: Owner could have saved $725,000 in 18 months***

SAFELY DEFERRING REPLACEMENT

- ***Problem: City can't afford to replace 15 deficient short-span bridges***
- ***Customer: City of Phoenix***
- ***Objectives:***
  - ***Conduct initial load test***
  - ***Stiffen bridge with CFRP wrap***
  - ***Monitor for 12 months to be sure***
- ***Results:***
  - ***Bridge is stiffer; rates for HS-20***
- ***Conclusion: Owner saves ~$3 million dollars on one bridge by using a unique repair technique***

REPAIR ASSESSMENT



- ***Problem: Were the fracture critical retrofits effective?***
- ***Customer: Pennsylvania DOT***
- ***Objectives:***
  - ***Monitor for 7 months***
  - ***Develop calibrated model with data***
- ***Results:***
  - ***Accurate FE model usable for ongoing bridge management***
  - ***One location identified with significant strain excursions***
- ***Conclusion: Monitoring data and FEM identified several "hot spots" for targeted inspections***

REPAIR ASSESSMENT

- <u>Problem</u>: Was the innovative deck repair method effective?
- Customer: <u>Caltrans</u>
- Objectives:
  - Monitor before repair for gap movements.
  - Monitor after for several months to confirm repairs worked.
- Results:
  - Initial monitoring confirmed problem.
  - Subsequent monitoring confirmed repair worked.
- <u>Conclusion</u>: DOT confidently used the repair method to save millions vs. replacements

STEEL FLOORBEAM CRACK REPAIR

- Problem: Deck framing reaching end of life; unexpected steel cracking.
- Owner: Upper Midwest Toll Bridge
- Objectives:
  - Measure displacements at as-designed locations and proposed repairs.
  - Monitor for several months to confirm repairs worked as expected.
- Results: Repair method worked as intended.
- **Conclusion: Owner spends $75,000; analysis supports safe deferral of ~$25,000,000 repair program.**

OUT-OF-PLANE BENDING

- ***Problem: Stringers heavily corroded at flange/web interface***
- ***Customer: TBTA, NYC***
- ***Objectives:***
  - ***Couple two types of technologies to monitor ongoing deterioration***
  - ***Evaluate efficacy of both for more extensive deployment***
- ***Results:***
  - ***Wireless communication challenges in NYC***
  - ***Sensors captured peak displacement, despite loss of power***
- ***Conclusion: Major rehab project (>$30MM) safely deferred***

ADVICE FOR PRACTITIONERS

- *Be sensitive to your client's lack of funding; develop less expensive options*
- *Evaluate monitoring solutions, especially if driven by the superstructure condition*
- *Don't shortchange monitoring periods or analytics*
- *Ensure a return on investment; monitoring is not research*
- *Structural monitoring is fully commercial, but use highly experienced firms*

PART III – LEE FLOYD, PE
SCDOT
STATE BRIDGE MAINTENANCE ENGINEER

SCDOT'S TIDP PROGRAM

- ***US 29 @ Savannah River (Anderson)***
- ***I-77 NB @ SC 901 (York)***
- ***I-77 SB @ SC 901 (York)***
- ***SC 277 @ I-77 NB (Richland)***
- ***US 21 Bus. @ Beaufort River (ICWW) (Beaufort)***
- ***US 17 SB @ South Santee River (Georgetown)***
- ***US 17 @ Cooper River (Ravenel) (Charleston)***
- ***US 17 SB @ Ashley River (Charleston)***

QUESTIONS?