Performance of Geosynthetic Reinforced Soil Integrated Bridge Systems (GRS IBS)

October 24, 2016

TRB Webinar

Sponsor: Geosynthetics Committee (AFS70)

Cosponsor: Transportation Earthworks Committee (AFS10)

Jennifer Nicks, P.E., PhD – *Federal Highway Administration*
Christopher Meehan, P.E., PhD – *University of Delaware*
Derrick Dasenbrock, P.E. – *Minnesota DOT*
Peter Connors, P.E. – *Massachusetts DOT*
Daniel Alzamora, P.E. – *Federal Highway Administration*

Agenda

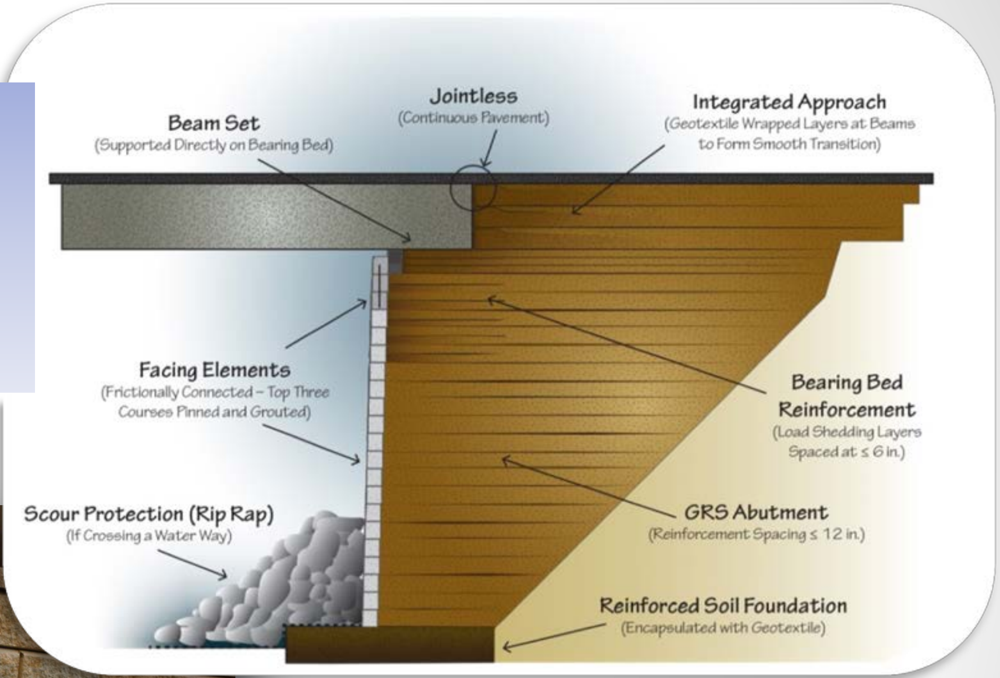
Time	Topic	Presenter
15 min	Introduction and technology overview	Jennifer Nicks, P.E., PhD Federal Highway Administration
15 min	Chesapeake City Road, DE (2013)	Christopher Meehan, P.E., PhD University of Delaware
15 min	CR 55 over Minnesota Southern RR, MN (2013)	Derrick Dasenbrock, P.E. Minnesota DOT
15 min	RT 7A Over Housatonic RR, MA (2014)	Peter Connors, P.E. Massachusetts DOT
5 min	Summary of GRS IBS performance & national deployment efforts	Daniel Alzamora, P.E. Federal Highway Administration
25 min	Questions and Answer Sessions	Panel

Introduction and technology overview

Jennifer Nicks, P.E., PhD – *Federal Highway Administration*

What is GRS IBS?

- Accelerated construction technique
- Utilizes compacted granular fill and geosynthetic reinforcement in alternating layers for bridge support



Beam Set
(Supported Directly on Bearing Bed)

Jointless
(Continuous Pavement)

Integrated Approach
(Geotextile Wrapped Layers at Beams to Form Smooth Transition)

Facing Elements
(Frictionally Connected – Top Three Courses Pinned and Grouted)

Bearing Bed Reinforcement
(Load Shedding Layers Spaced at ≤ 6 in.)

Scour Protection (Rip Rap)
(If Crossing a Water Way)

GRS Abutment
(Reinforcement Spacing ≤ 12 in.)

Reinforced Soil Foundation
(Encapsulated with Geotextile)

GRS – Composite Material

Concrete

- Aggregate
- Water
- Cement

GRS

- Aggregate
- Closely-spaced geosynthetics

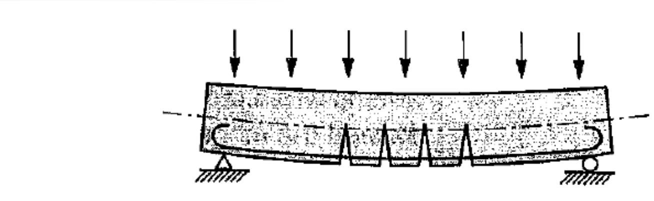
Aggregate → Aggregate

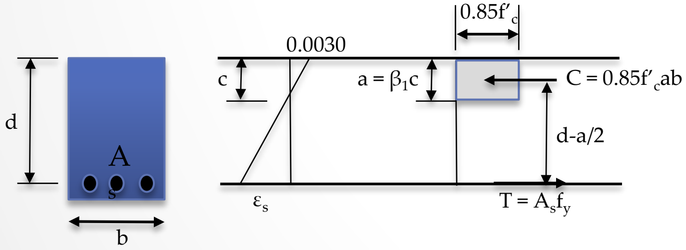
Water, Cement → Closely-spaced geosynthetics

GRS– Composite Design

Concrete

- Steel reinforcement (rebar) provides the tensile strength





GRS

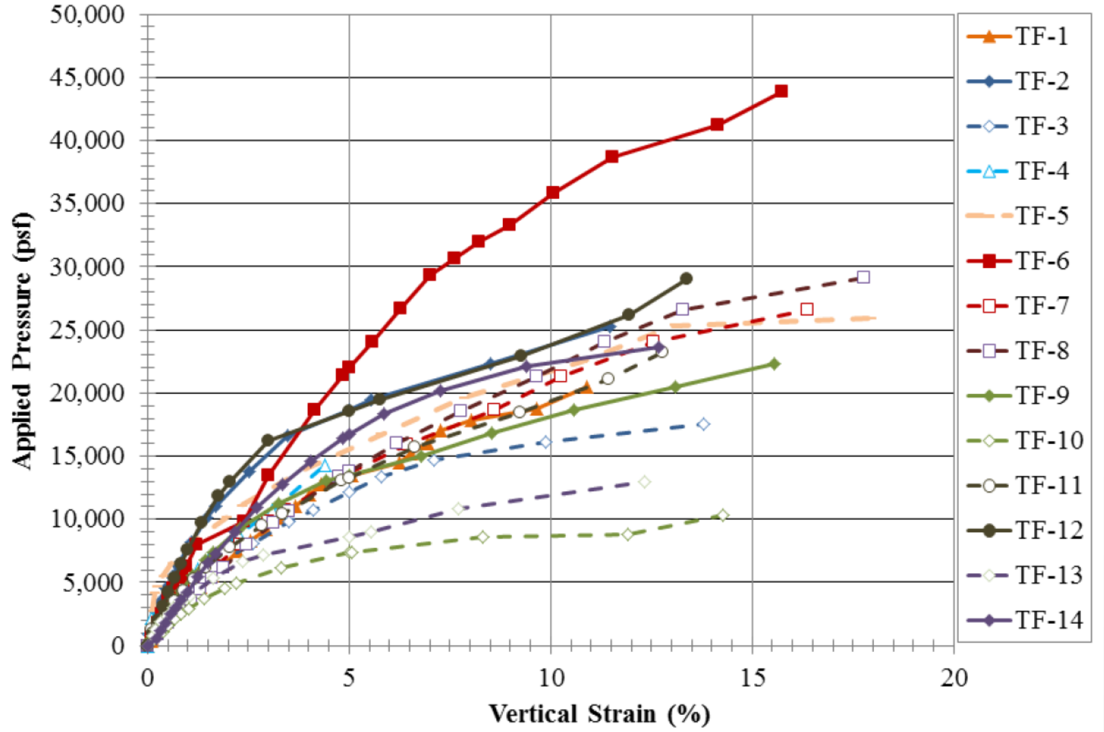
- Geosynthetic reinforcement provides tensile strength (and added compressive strength)

S_v = 32″ 28″ 24″ 20″ 16″ 12″ 8″ 4″

GRS IBS – Composite Design

GRS Abutments

- Spacing and properties of the reinforcement plays a role in strength and serviceability
- The backfill and facing element also play a role in developing a unique composite with measurable properties that can be used in design



Reinforced Backfill

Open Graded Fill

Well Graded Fill

Geosynthetics

Geogrids

Geotextiles

Facing Element

Why Consider the GRS IBS

- Lower costs (20-60%)
- Accelerated bridge construction
- Smooth transition alleviated the "bridge bump"
- Good performance

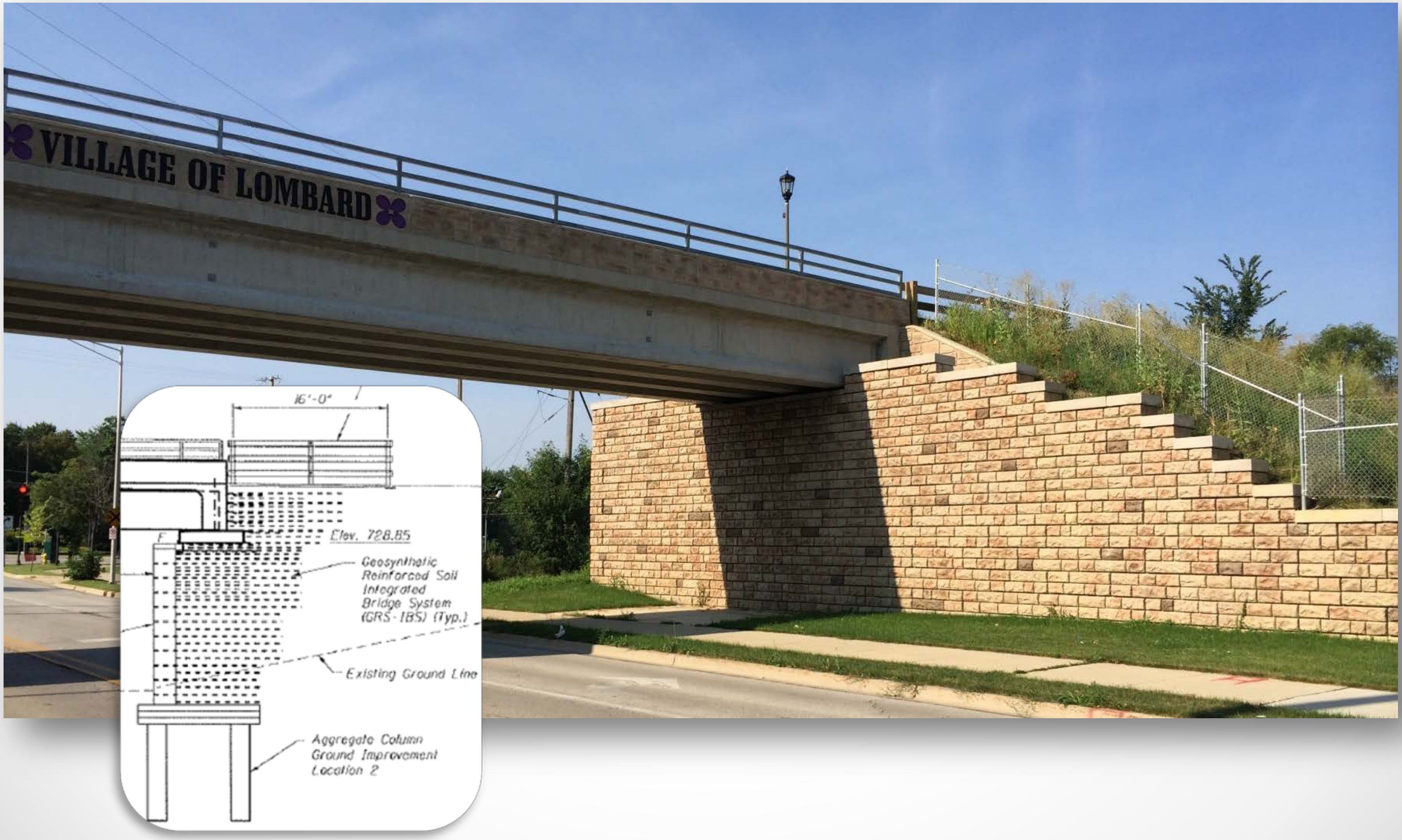
Where to Consider the GRS IBS

- Grade separations
  - Grade crossings of road, rail, trails
- Water crossings
  - Creeks, rivers, flood plains, tidal zones

- Low volume local roads
- High volume and high loads
- Bridges under various load combinations
  - e.g. seismic, lateral, thermal, uplift
- Unusual geometries
  - e.g. skew, longitudinal grades, transverse grades
- Various superstructure types
  - e.g. adjacent concrete boxes, steel girders with semi-integral abutment, timber bridges, trusses

IL – Great Western Trail *(over Grace St.)* (2011)

Use of stone columns to improve foundation soils



ME - Knox County Beach Bridge (2013)

HI – Saddle Road Bridge (2012)

Designed for PGA x F_{pga} ground acceleration (PGA=0.6g F_{pga}=1.0)

Taken October 2014, 2 years after construction

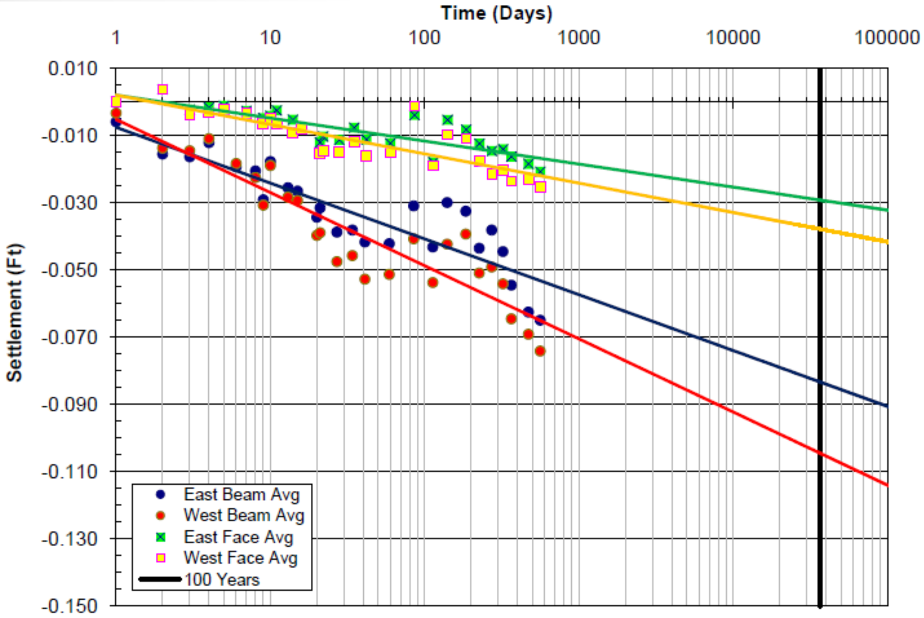
NY – CR 38
St. Lawrence County (2013)

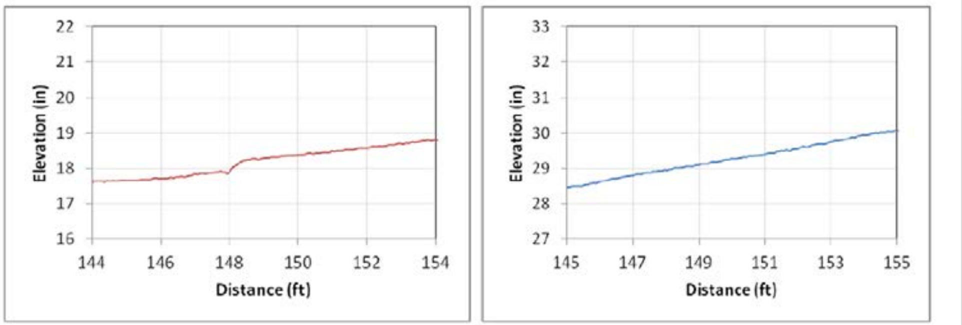
Where <u>not</u> to Consider the GRS IBS

- Areas with deep scour estimates
- Areas with highly compressible foundation soils, unless considering ground improvement techniques

Performance of GRS-IBS

- First GRS IBS built in 2005 (24° skew, 7.6° superelevation, 0.006 ft/ft grade)
- An additional four bridges were instrumented and monitored, with the longest span of 140 feet.
- Results indicated good performance, small deformations, and no bump at the end of the bridge





Key Performance Indicators of GRS-IBS

- Vertical settlement
  - (survey, LiDAR, etc.)
- Lateral wall face deformations
  - (survey, LiDAR, inclinometers, etc.)
- Super-Substructure thermal interactions
  - (visual observations, contact pressure cells, strain gauges, inclinometers, etc.)
- Differential settlement between the bridge and approach
  - (profilers, survey, etc.)
- Differential settlement across the abutment length
  - (survey, horizontal inclinometers, etc.)

Case Histories

Chesapeake City Road, DE

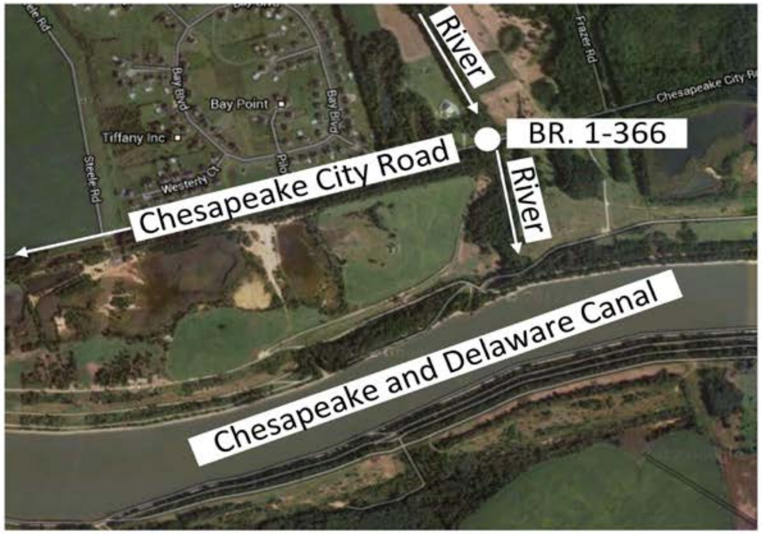
RT 7A Over Housatonic RR, MA

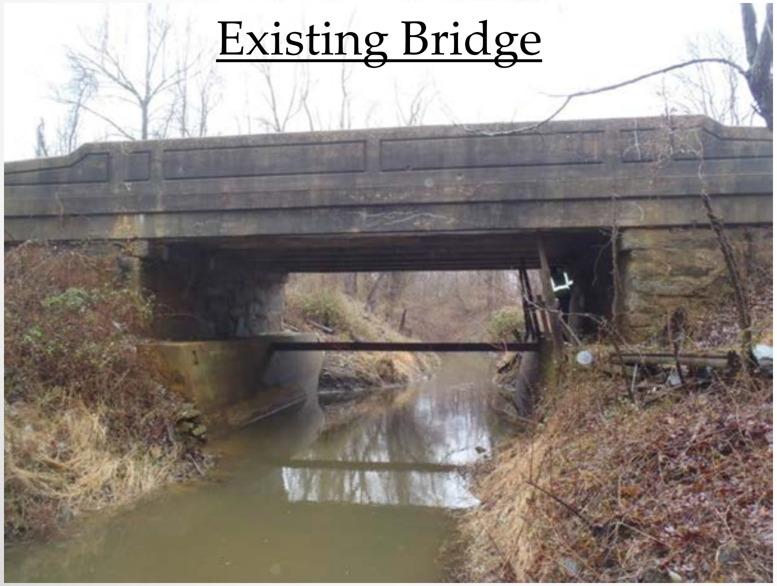
CR 55 over Minnesota Southern RR, MN

Chesapeake City Road (2013)

Christopher Meehan, P.E., PhD – *University of Delaware*

Bridge 1-366 on Chesapeake City Road

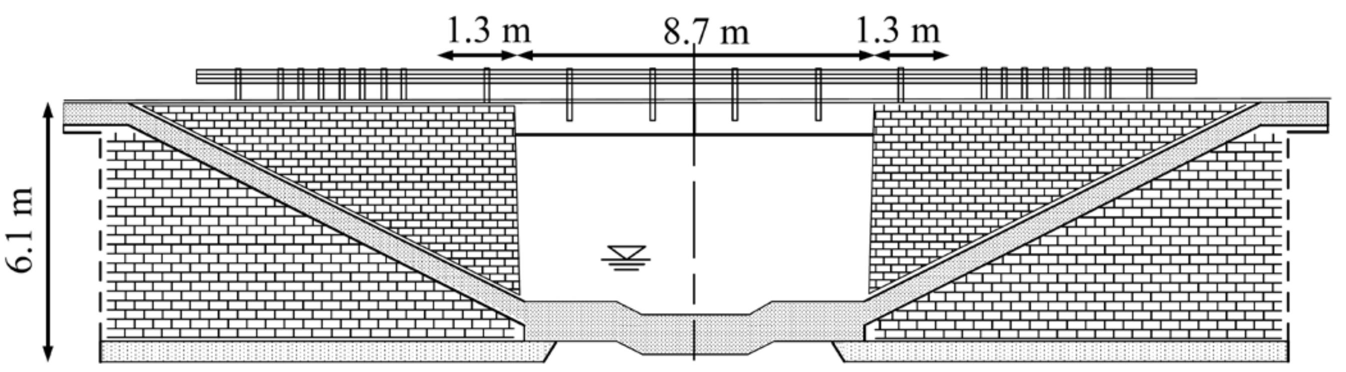


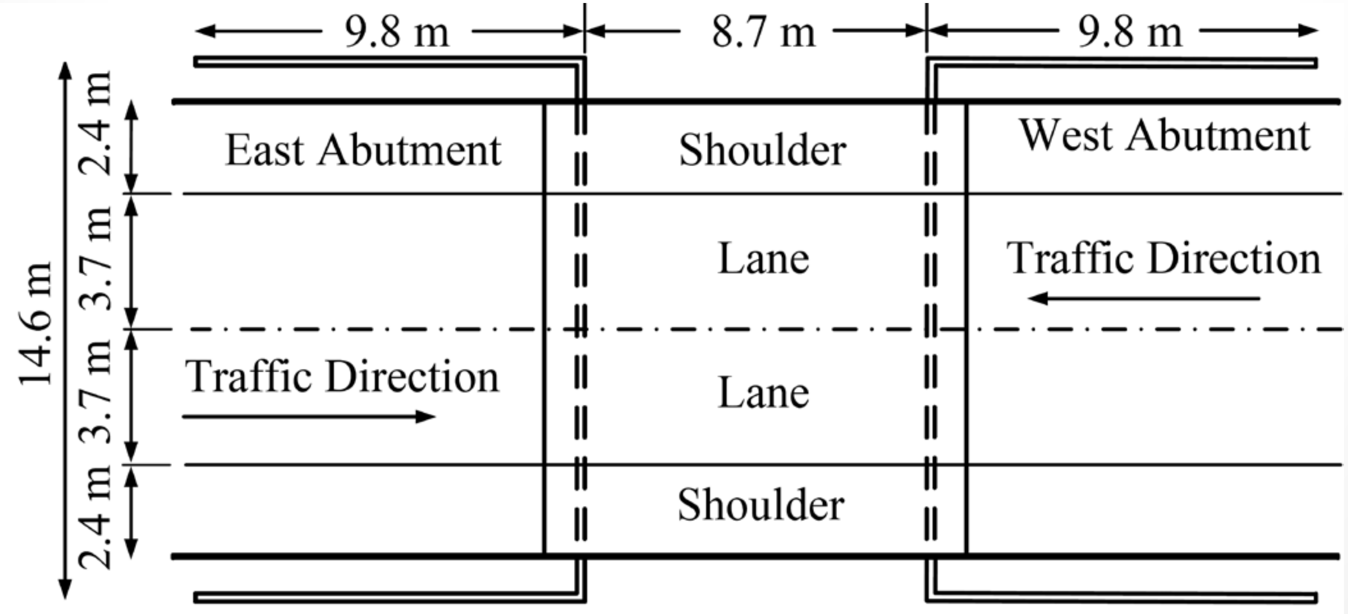


Existing Bridge

- AADT = 2617
- 3/19/13-3/21/13: Existing bridge demolition
- 3/22/13 – 4/5/13: East abutment excavation and construction
- 4/3/15 – 4/23/15: West abutment excavation and construction
- 4/25/13: Placement of bridge beams
- 4/26/13 – 5/4/13: Integration zone construction

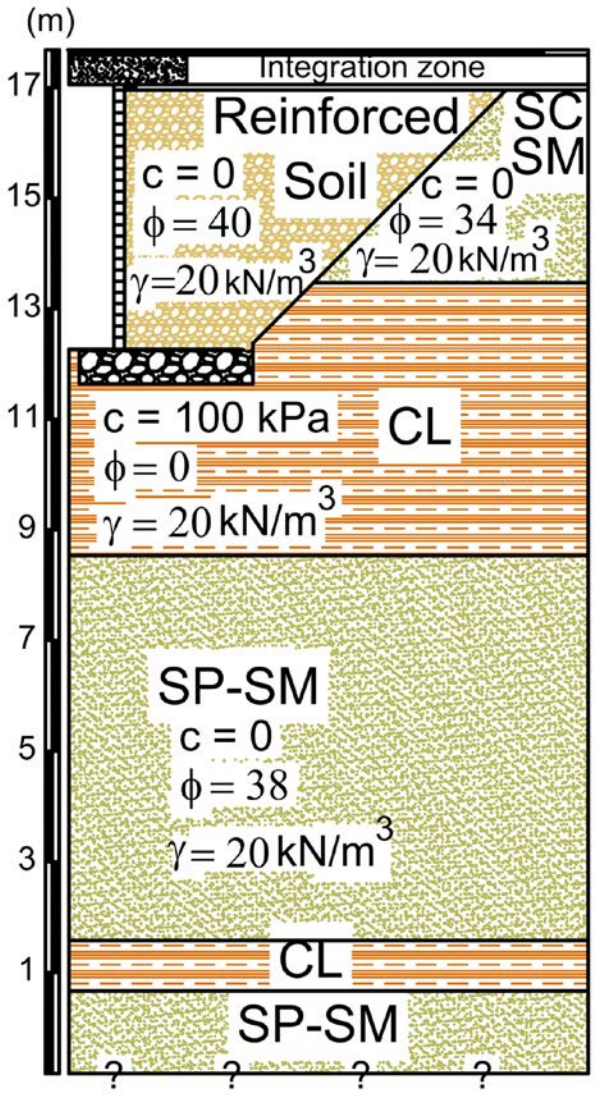
Geometric Specifications for Project





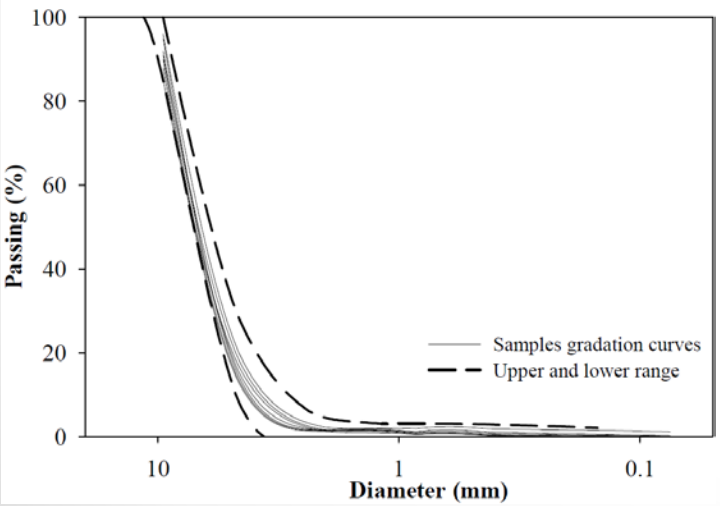
Geotechnical Conditions at the Site

- 2 HSA soil borings with SPT sampling – one through the center of each existing abutment
- In second boring, continuous Shelby tube sampling was performed over clay layer immediately beneath GRS-IBS
- Laboratory tests performed:
    - 41 soil classification tests – grain size analysis and Atterberg limits
    - 6 one-dimensional consolidation tests
    - 2 unconfined compression tests
    - 4 unconsolidated undrained triaxial tests
    - 11 organic content tests



Materials Used for GRS Abutment Construction

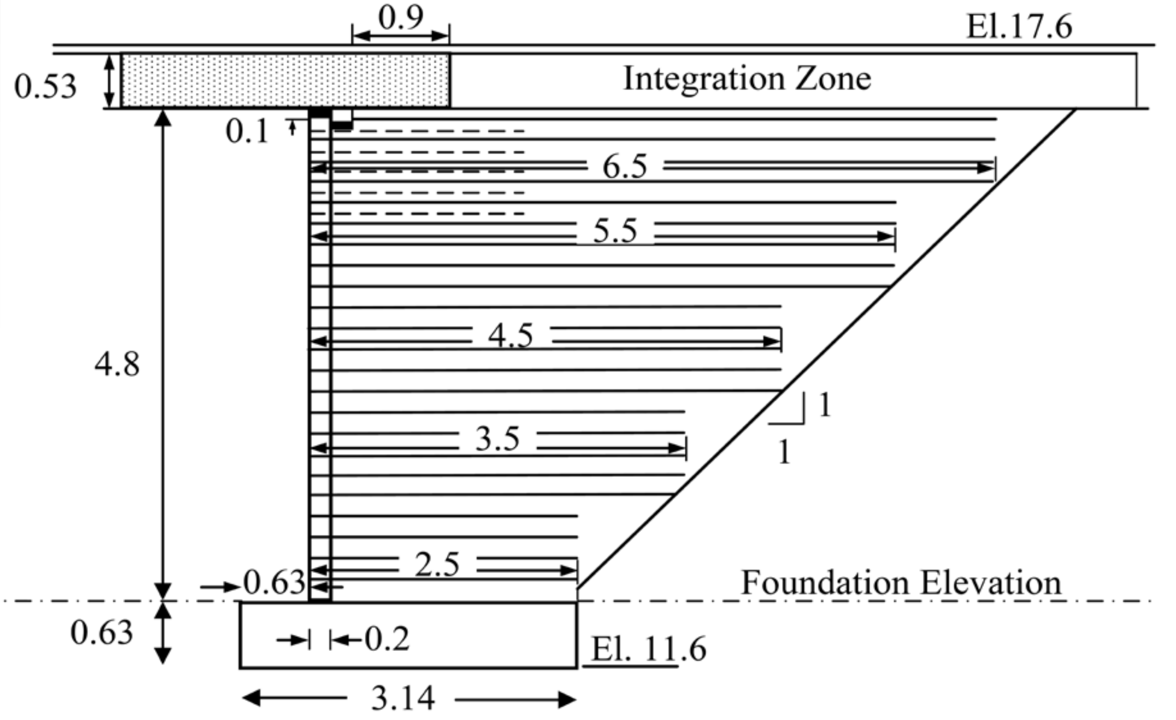
No. 8 Stone Backfill for Reinforced Zone



Polypropylene Woven Fabric Geotextile

Property	Test Method	Value
Wide Width Tensile Strength (Maximum)	ASTM D4595	70.0 x 70.0 kN/m
Wide Width Tensile Strength (2% Strain)	ASTM D4595	14.0 x 19.3 kN/m
Wide Width Tensile Strength (5% Strain)	ASTM D4595	35.0 x 39.4 kN/m

Resulting GRS-IBS Design Section



(All dimensions shown are in m)

Design was performed following the 2011 “Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide”, Publication No. FHWA-HRT-11-026

- External Stability Analysis
    - Direct sliding
    - Bearing capacity
    - Global stability
- Internal Stability Analysis
    - Ultimate capacity
    - Vertical & horizontal deformation
    - Required reinforcement strength

GRS-IBS CONSTRUCTION PROCESS

Construction

West Abutment

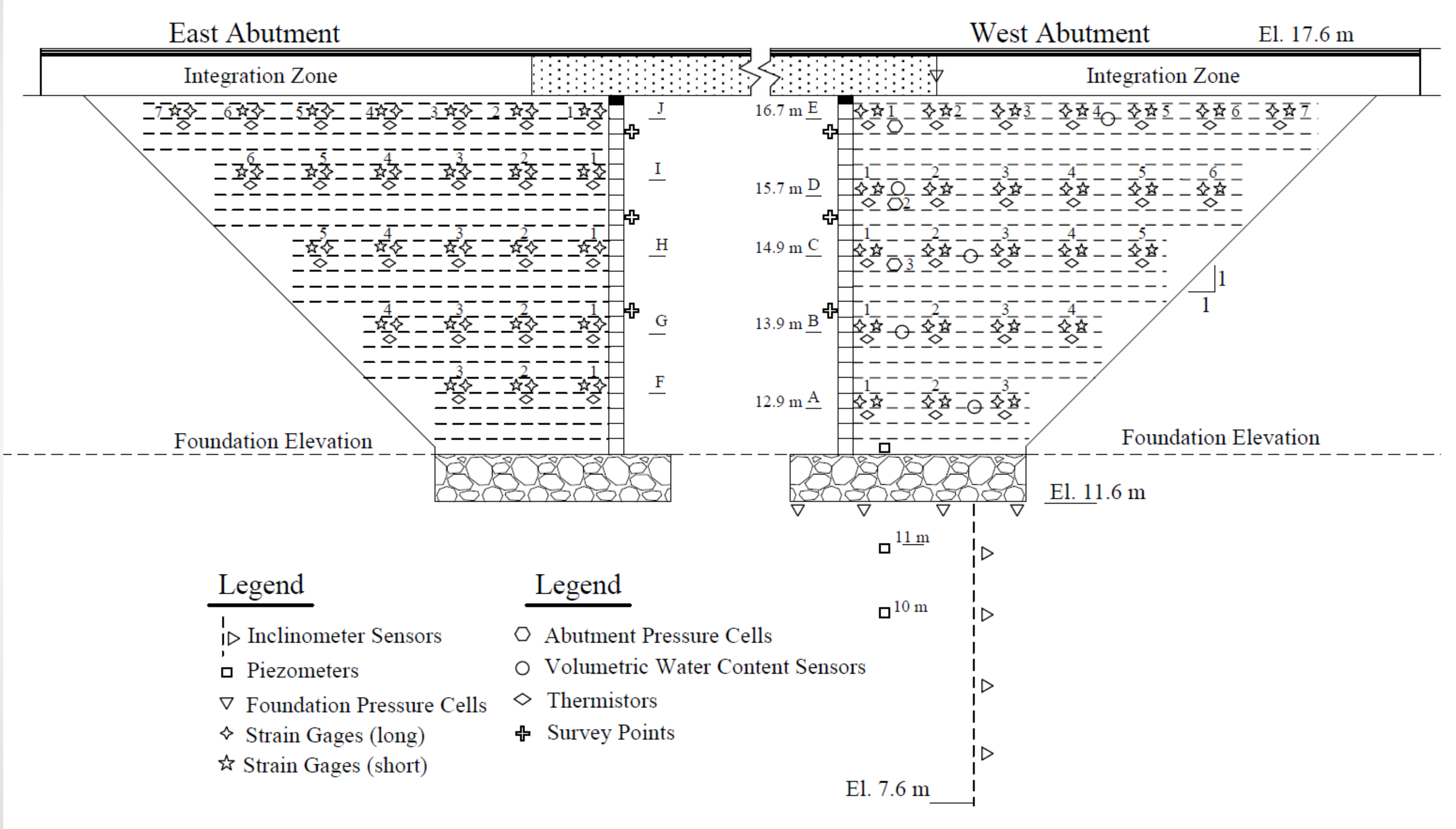
Bridge Superstructure Construction

Bridge Placement and Approach Road Construction

New Bridge 1-366

INSTRUMENTATION
&
MONITORING

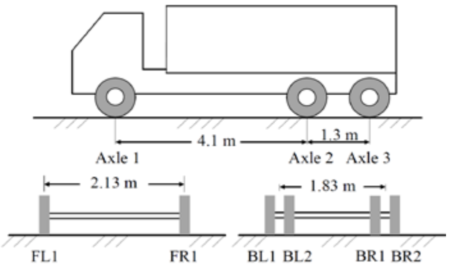
Instrumentation Profile

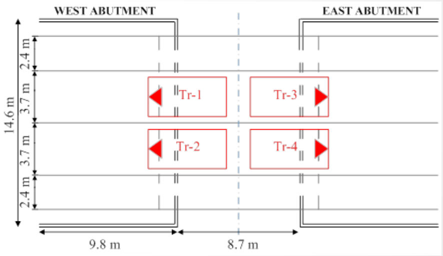


Three Phases of Project Monitoring

Construction

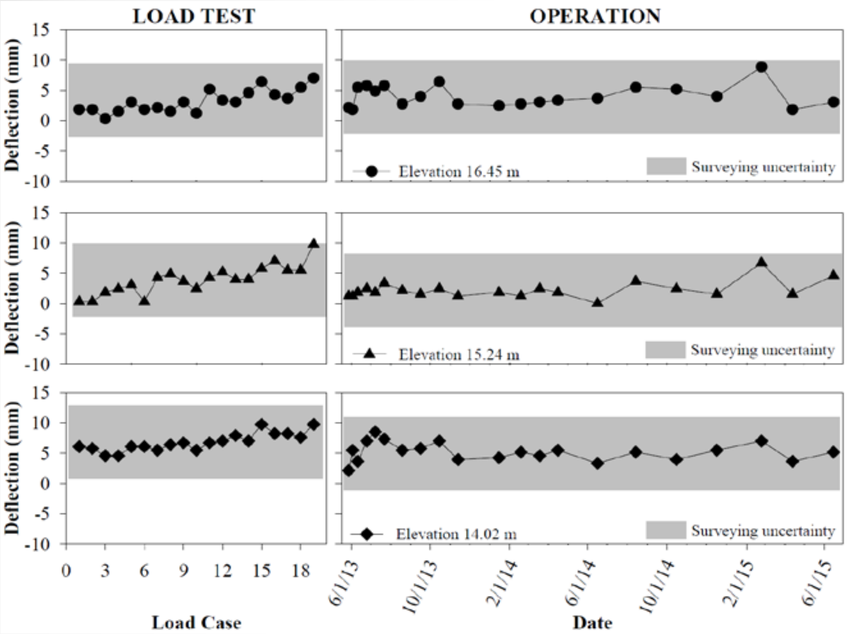
Live Load Testing



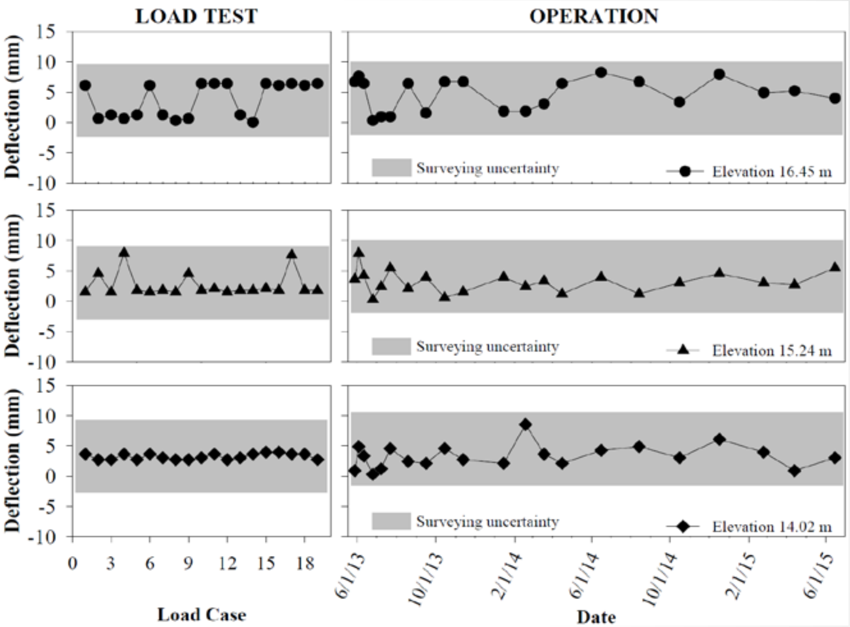


Long Term Monitoring

Deflection of GRS-IBS Wall Facing Blocks



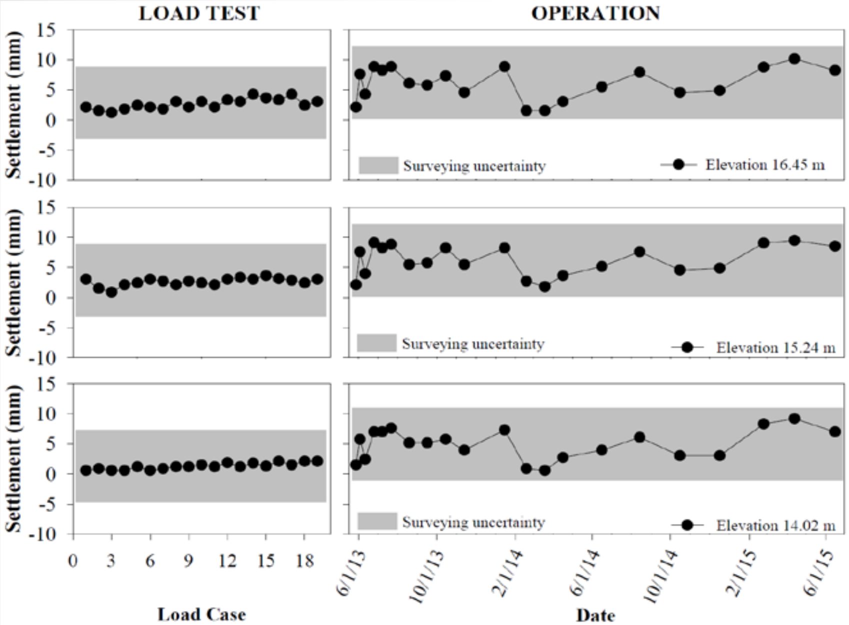
West Facing Wall at
Abutment Centerline



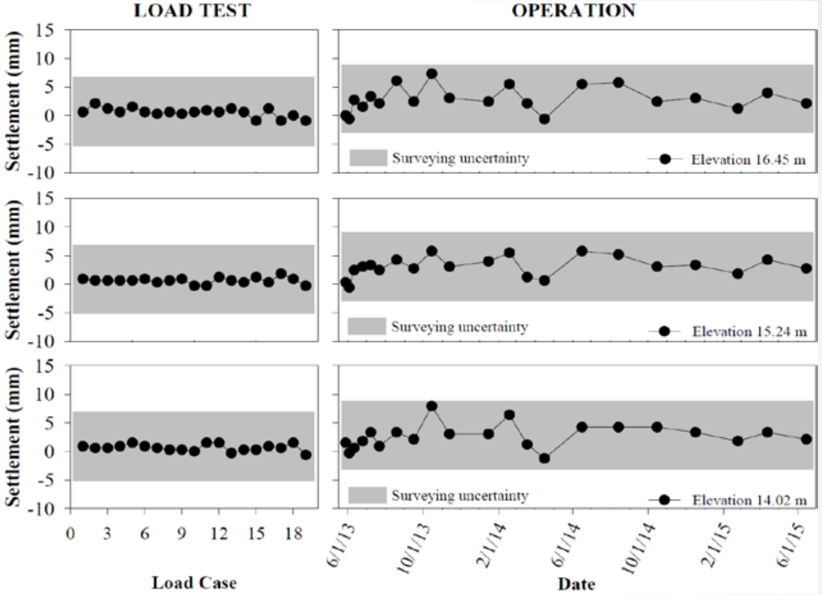
East Facing Wall at
Abutment Centerline

- The measurement precision and resolution for the utilized surveying system was 6 mm and 0.3 mm, respectively.
- The maximum facing wall lateral deflection at the abutment centerline is less than 10 mm.

Settlement of GRS-IBS Wall Facing Blocks



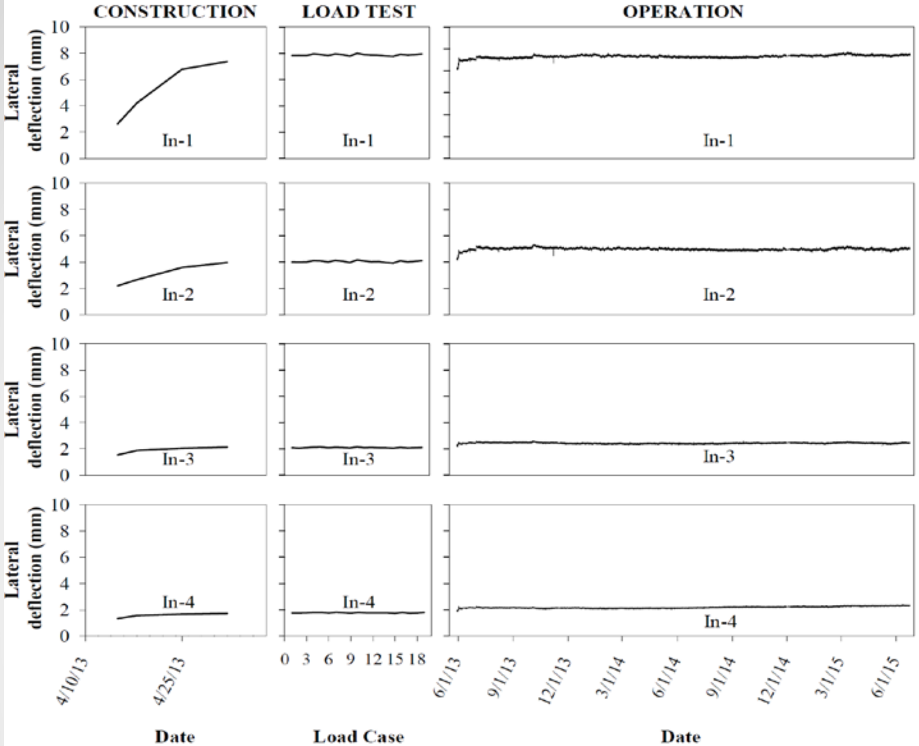
West Facing Wall at
Abutment Centerline

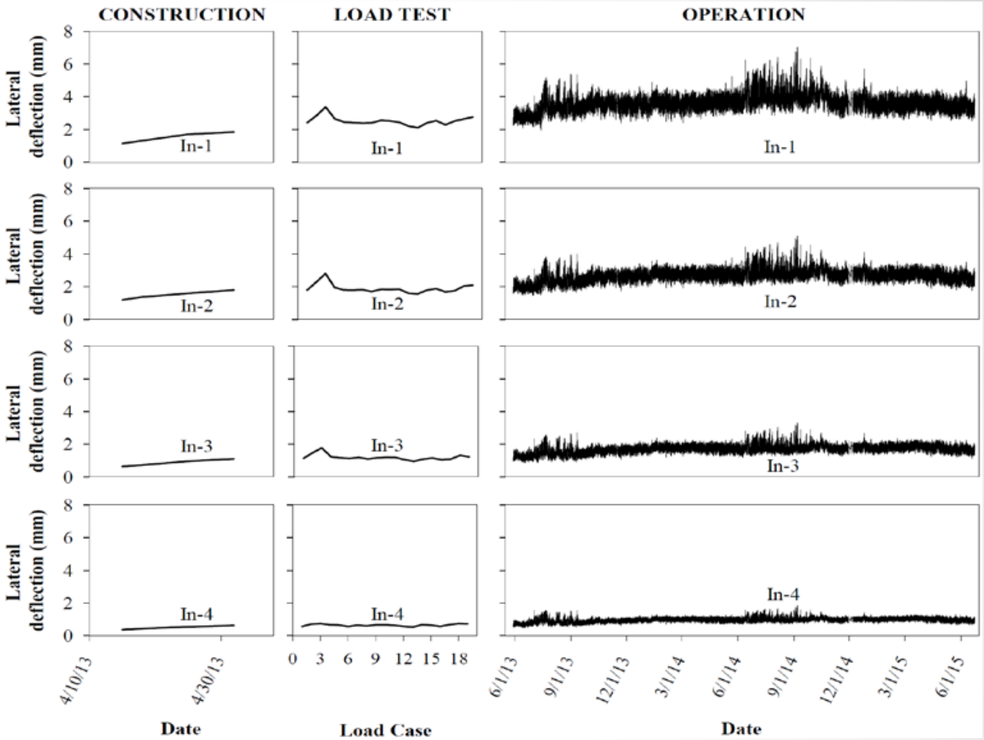


East Facing Wall at
Abutment Centerline

- The measurement precision and resolution for the utilized surveying approach was 6 mm and 0.3 mm, respectively.
- The maximum facing wall settlement at the abutment centerline is less than 12 mm.

Deformation in the GRS-IBS Foundation





Inclinometer Deflection: E-W Direction

Inclinometer Deflection: N-S Direction

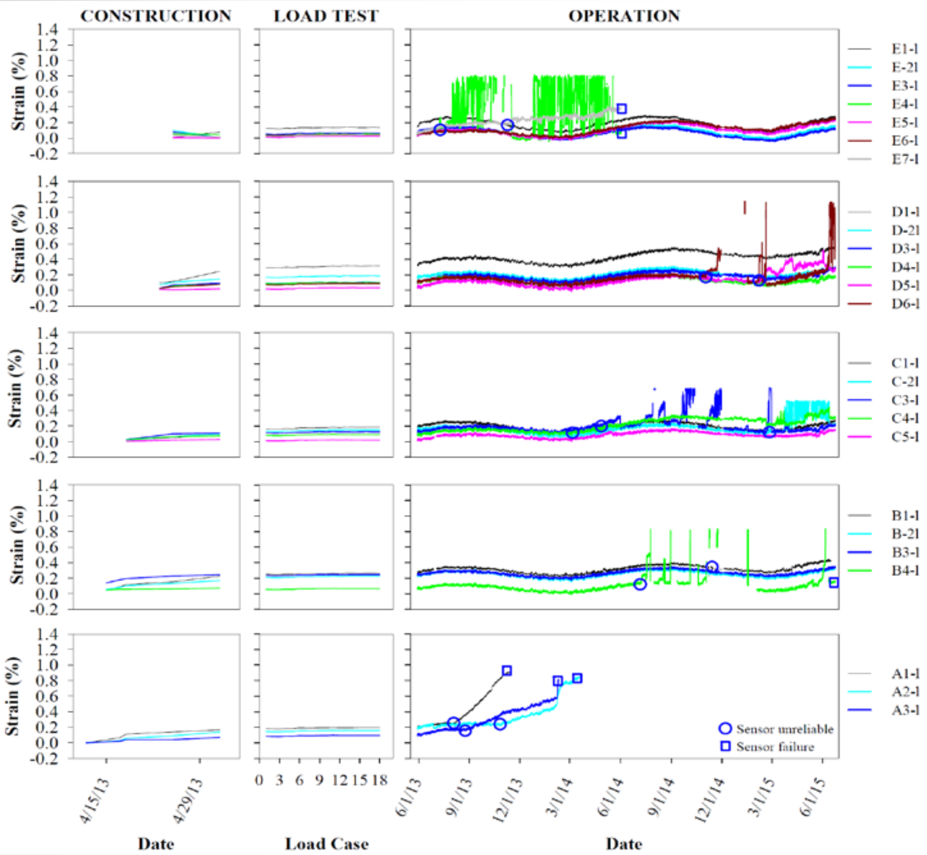
- The maximum deflection in E-W and N-S directions are 10 mm and 7 mm respectively.

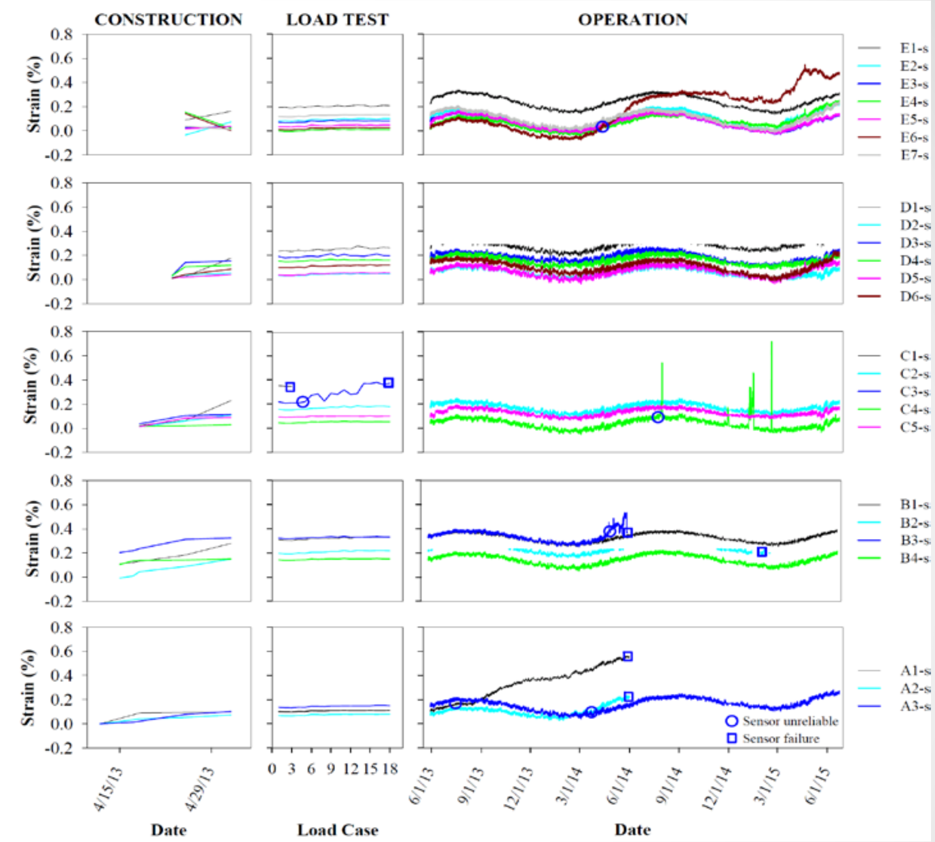
No “Bump at the End of the Bridge”

Construction of transition zone

Transition zone after two years of operation

Geosynthetic Strains Within the GRS Abutment





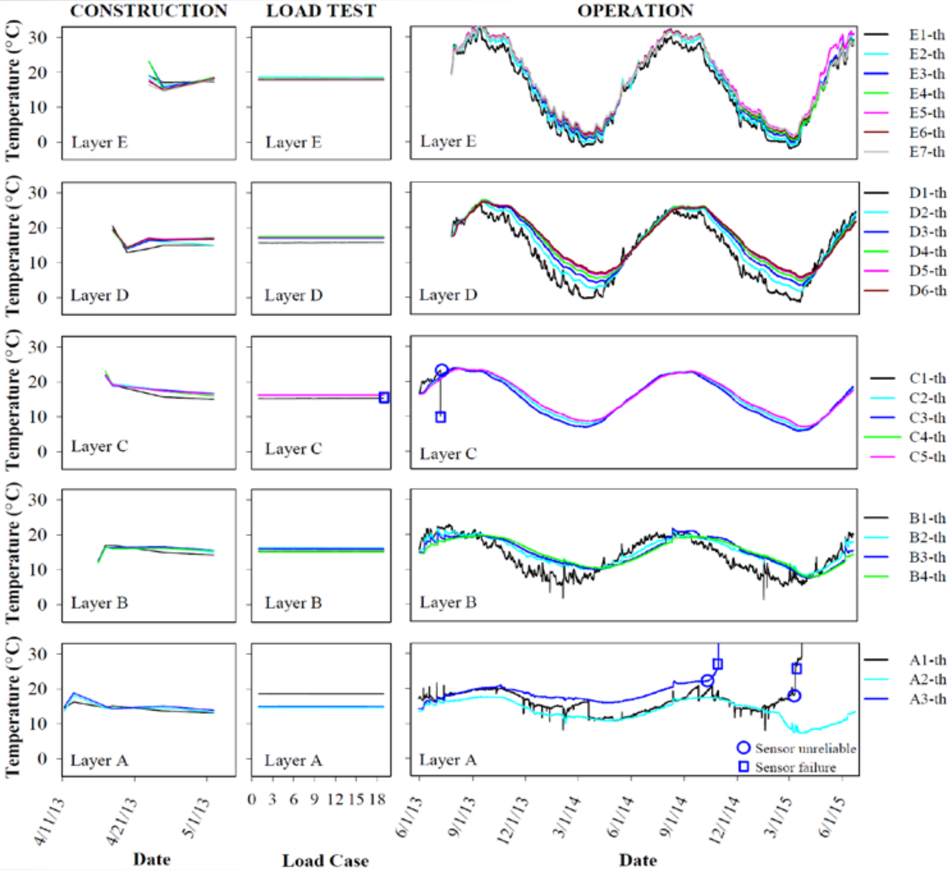
Long Strain Gauge

Short Strain Gauge

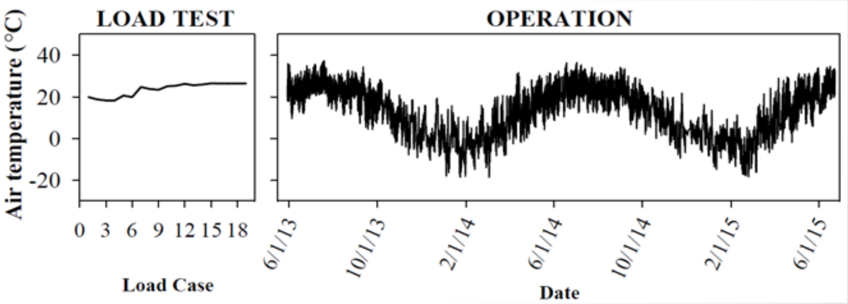
- The maximum strain in the abutment is less than 0.5%.
- The maximum creep in the abutment in less than 0.1%.
- No significant difference in long and short strain gauge measurements.
- No significant difference in the strains in the East and West abutments.

Temperature Within the GRS Abutment

- The temperature distribution in the abutment varies with the hot and cold weather.
- The upper elevations and the areas closer to the facing wall experience higher temperature changes due to being more exposed to the air temperature changes.

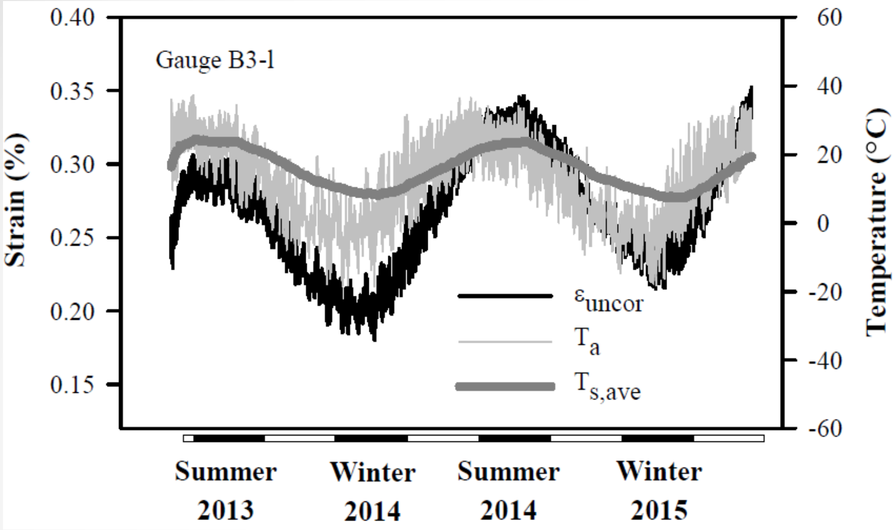


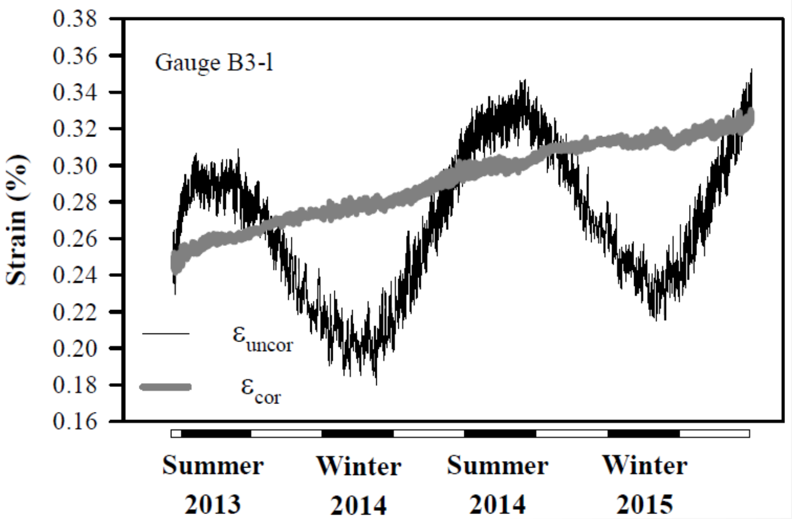
Temperature recorded by thermistors



Temperature recorded from accuweather.com

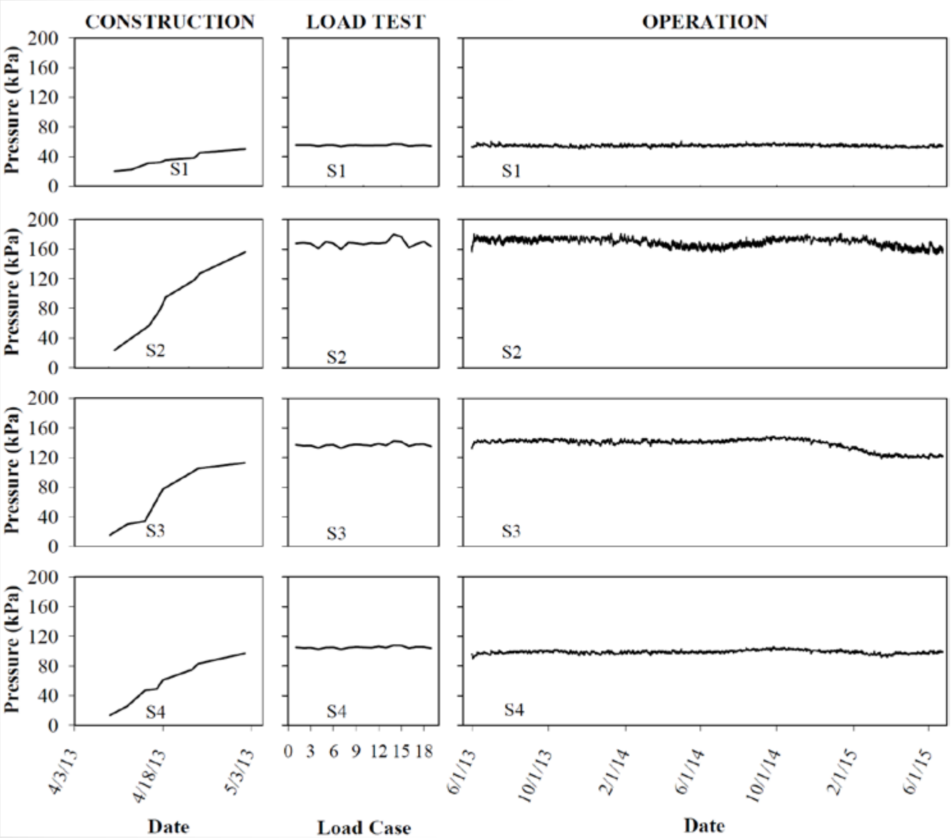
Correcting Measured Strains for Temperature Effects

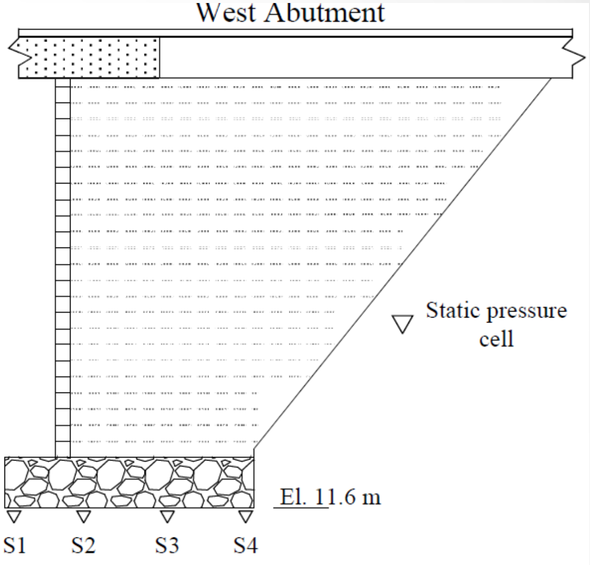


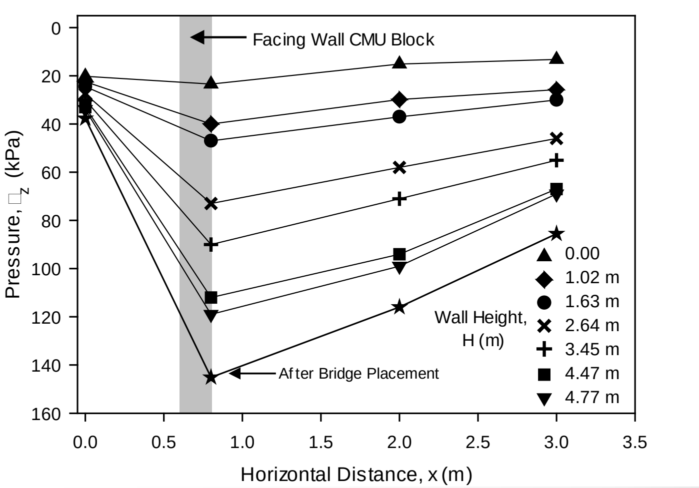


- A two-wire Wheatstone bridge configuration was used to wire foil strain gauges – measured results can be affected by temperature.
- A mathematical technique was developed for correcting strain gauge readings to account for temperature effects. Using this method, the temperature corrected strain (ε_{cor}) is determined using the measured strain (ε_{uncor}), air temperature (T_a), and average wire path temperature under the ground ($T_{s,avg}$).

Applied Bearing Pressure Beneath the Base of the RSF







Conclusions

Overall Conclusion: Satisfactory performance of the structure over the three phases of project monitoring.

- The maximum facing wall lateral deflection at the abutment centerline was less than 10 mm
- The maximum facing wall settlement at the abutment centerline was less than 12 mm
- Maximum strain in the abutments was less that 0.5%
- Maximum creep in the abutments was less that 0.1%
- Temperature had a direct influence on measured strain and should be corrected for
- No apparent scour issues

RAPID REPLACEMENT

To replace a two-lane bridge nearing the end of its design life, the Delaware Department of Transportation used an innovative approach. Built using geosynthetic reinforced soil abutments and prefabricated bridge superstructure elements, the composite bridge was constructed rapidly and has been equipped with a custom-designed instrumentation system to monitor long-term performance.

By Majid Talebi, P.E., S.M.ASCE, Christopher L. Meehan, Ph.D., P.E., M.ASCE, Daniel V. Cacciola, A.M.ASCE, and Matthew L. Becker, A.M.ASCE

To replace one of its bridges, the Delaware Department of Transportation decided to apply an innovative technology that uses geosynthetic reinforced soil as part of an integrated bridge system. To monitor the bridge's performance, an array of sensors was installed in the abutments.

UNIVERSITY OF DELAWARE, ALL IMAGES

AS THE NUMBER OF BRIDGES in need of repair or replacement continues to grow, the search for a cost-effective solution becomes increasingly important. In the field of retaining walls, the use of structures employing mechanically stabilized earth or geosynthetic reinforced soil (GRS) approaches has helped to decrease costs. As it happens, concepts from these technologies can also be applied to bridges, saving money and reducing construction time. In the first such project in the state of Delaware, a two-lane bridge nearing the end of its design life was replaced with what is known as a GRS integrated bridge system (IBS). Developed by the Federal Highway Administration (FHWA), this system yields a composite bridge structure featuring GRS abutments and prefabricated bridge superstructure elements. An innovative alternative to conventional bridge support technology, this system lends itself to rapid construction. This article describes the design and construction process for the GRS-IBS that was installed in Delaware and also outlines the custom-designed instrumentation system that was developed to monitor the structure's long-term performance.

A typical GRS-IBS utilizes closely spaced layers of geosynthetic reinforcement and compacted granular fill material to provide direct bearing support for structural bridge members. Compared with conventional bridges, this new technology has several unique advantages, including reduced construction time and cost, easier maintenance throughout the life cycle of the structure, and generally fewer construction difficulties. Furthermore, GRS-IBS technology can be constructed under a variety of weather conditions and typically performs well under both static and dynamic loading if designed and constructed properly. So far about 150 GRS-IBS structures have been designed or constructed in more than 35 states, as well as in the District of Columbia and Puerto Rico.

Because GRS-IBS technology had proved useful for rapid, cost-effective bridge construction in other regions of the United States, the Delaware Department of Transportation (DelDOT) decided to explore the effectiveness of this technology for use within its own bridge inventory. As a first step in this process, the agency applied the GRS-IBS approach to replace a bridge that had reached the end of its usable service life.

As the project owner, DelDOT managed the associated design and construction processes for this GRS-IBS project. Representatives from the University of Delaware worked closely with DelDOT personnel during this process to provide technical guidance. They also designed an innovative system of sensors that will monitor the performance of the structure for an extended period. The project construction was performed by a local Delaware contractor—Mumford and Miller Concrete, Inc., of Middletown—under the supervision of DelDOT field personnel.

The particularly innovative component of the integrated system used on this project is the GRS abutment, which is constructed by compacting high-quality granular soil and geosynthetic reinforcement in a series of thin alternating layers. Rather than being connected by pins or other structural connectors, facing elements at the front of the GRS abutment are connected only frictionally to the geosynthetic reinforcement. A variety of facing element types can be used; thus far concrete masonry unit blocks have been the most common for GRS-IBS deployments. Because of the close spacing of the reinforcement, the facing elements are not required to hold back a significant mass of soil, and stress arching between soil reinforcement layers can play a significant role. Consequently, pinned connections are not necessary for the facing blocks, in

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Rapid Replacement

(Continued from Page 69) content sensors were installed in the west abutment to monitor soil moisture and its effect on strains in the geotextile. Fifteen surveying points were affixed to each abutment face to monitor settlements and wall deflections during the GRS-IBS construction process and while the structure is in service.

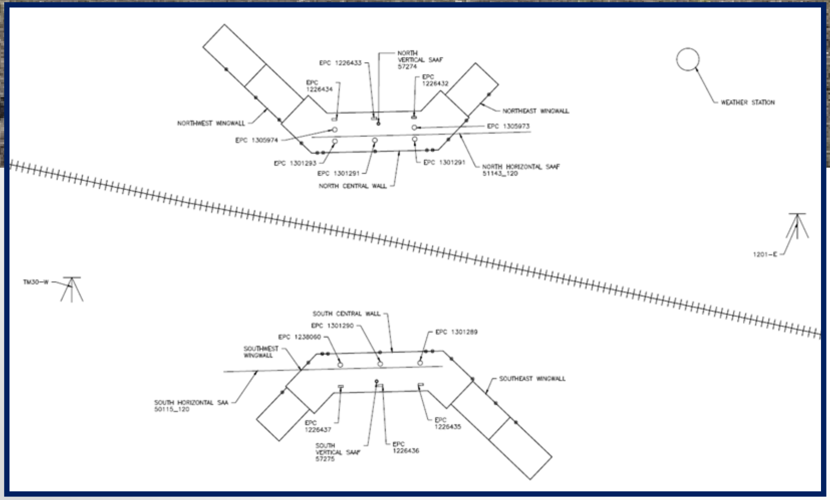
Thus far the first GRS-IBS constructed in Delaware has exhibited excellent performance. DelDOT personnel have been pleased with the straightforward nature of GRS-IBS construction, and the agency is looking for other projects suitable for this new technology. **CE**

Majid Talebi, P.E., S.M.ASCE, is a graduate student in the civil and environmental engineering department at the University of Delaware, and Christopher L. Meehan, Ph.D., P.E., M.ASCE, is an associate professor who holds the Bentley Systems Incorporated Chair of Civil Engineering there. Daniel V. Cacciola, A.M.ASCE, a former graduate student in the civil and environmental engineering department at the University of Delaware, is a geotechnical designer in the Mount Laurel, New Jersey, office of Gannett Fleming, Inc. Matthew L. Becker, A.M.ASCE, also a former graduate student in the civil and environmental engineering department at the University of Delaware, is an engineer in the Cleveland office of GRL Engineers, Inc. This article is based on a paper the authors presented at Geo-Congress 2014, which was sponsored by ASCE and its Geo-Institute and held February 23–26 in Atlanta. The authors note that the work reported here was supported by the Delaware Department of Transportation. This project was carried out using funds from the Federal Highway Administration's Innovative Bridge Research and Deployment Program. The authors would also like to express their gratitude to Michael Adams and Jennifer Nicks at the Federal Highway Administration for their support and guidance during the project and to Michael Davidson and Gary Wenczel at the University of Delaware for their assistance in the laboratory and the field.

PROJECT CREDITS Owner and designer: Delaware Department of Transportation **Technical oversight and sensor development:** University of Delaware **General contractor:** Mumford and Miller Concrete, Inc., of Middletown, Delaware **Geotextile provider:** Hanes Geo Components, Winston-Salem, North Carolina

Rock County Road 55 over MN Southern Railway

Derrick Dasenbrock, P.E. – Minnesota DOT



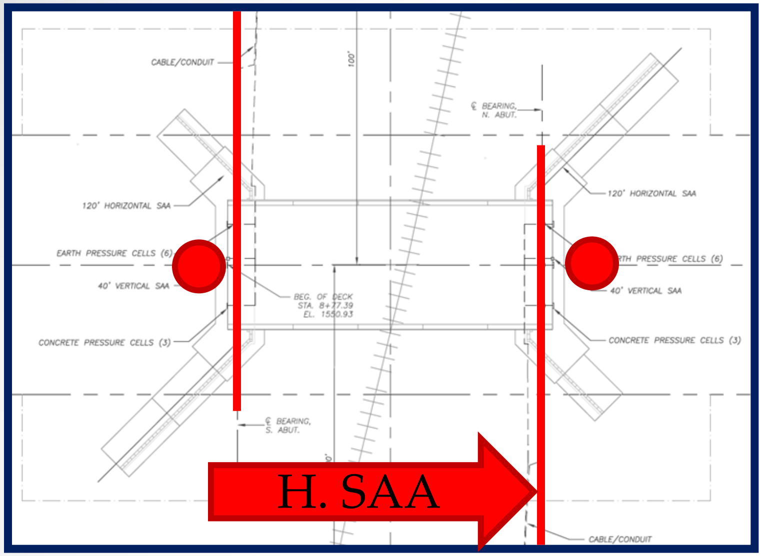
Derrick Dasenbrock, PE
Geomechanics/LRFD Engineer
Minnesota Department of Transportation

Project Summary

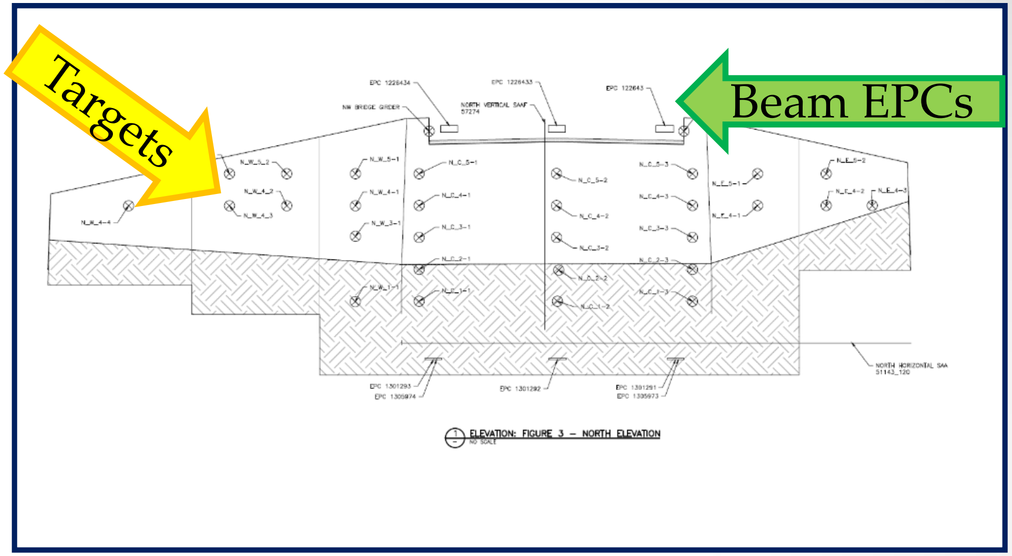
- Rock County (County State Aid Highway) Bridge 67564
- 5.3% grade (largest grade of an IBS built to date)*
- Length: 82.5′ (clear span 77.5′)
- Face height of 22′
- Width: 33′
- ADT 135

- Instrumentation Program Evaluated:
  - Construction behavior
  - *Reaction of GRS wall to bridge constructed at this grade
  - Deformation and movement during thermal cycles
  - 3-year post-construction monitoring

Instrumentation Layout Plans + X-Sec

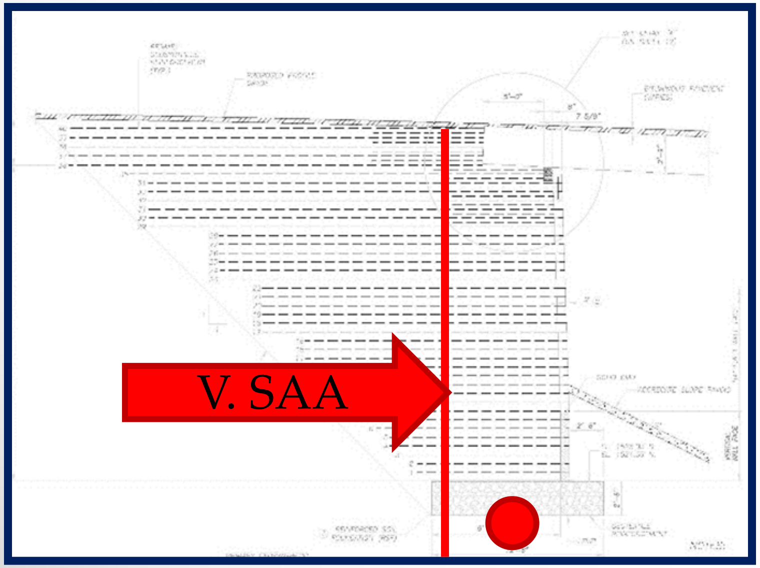


H. SAA

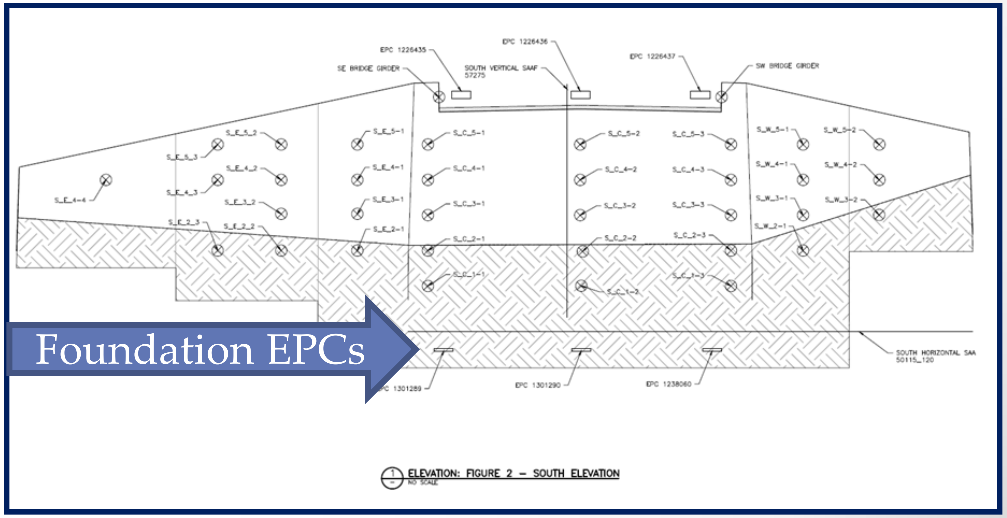


Targets

Beam EPCs



V. SAA



Foundation EPCs

Instrumentation Sensors and Equipment

- Each Abutment (N/S)
- 1 Vertical ShapeAccelArray @ center behind wall (2)
- 1 Horizontal ShapeAccelArray behind front face (2)
- 3-5 Earth Pressure Cell below reinforced soil foundation (8)
- 3 Fat Back EPC at back interface of bridge beams (6)
- 1 AMTS: NE*, SW (2 initially; *1 long-term)
- Optical Prisms on Face and on exterior beams (about 60)
- Support Equipment
    - Weather Station + Cameras + Solar Panels
    - Radios + Cell Modems + Batteries
    - Cabinets + Conduit + Cables
    - Back-sight Reference Prisms and Posts

Total numbers in ( )

Internal + External Instrumentation

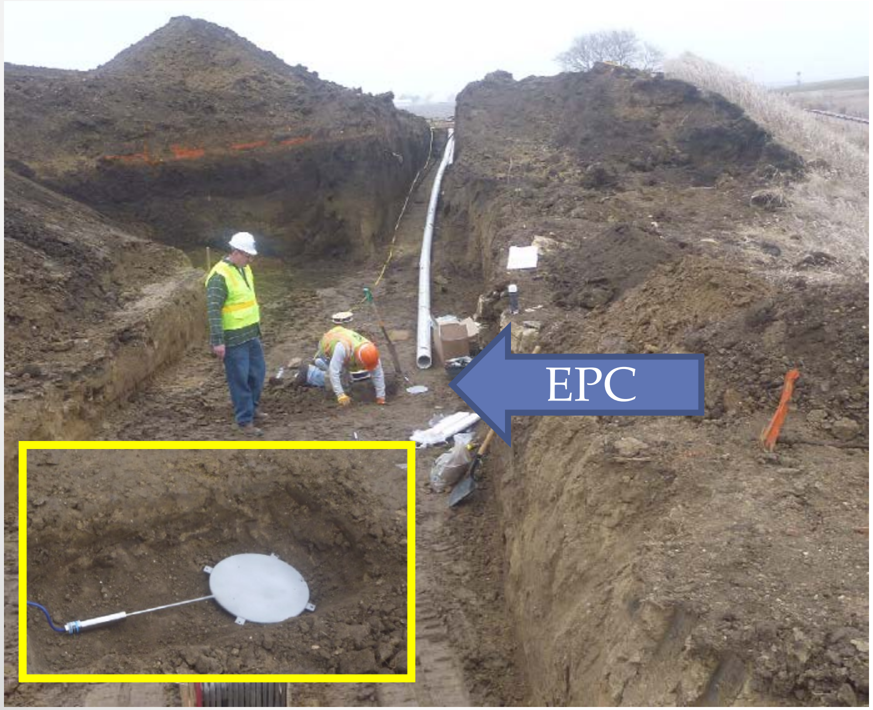
Sensors and targets installed throughout construction of the bridge

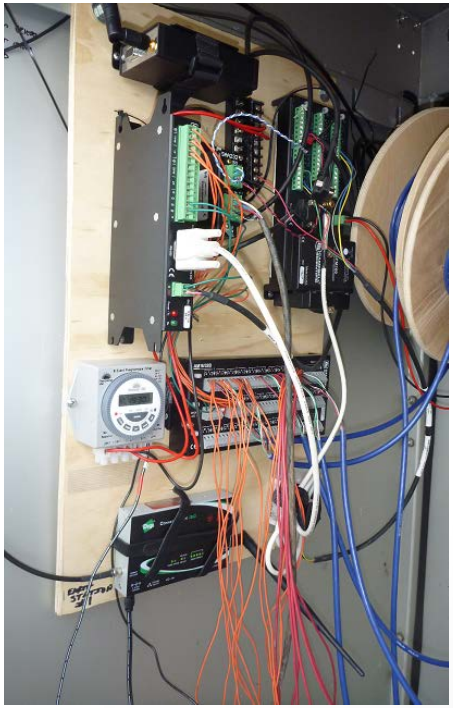
Many comments were received with respect to the number of strange looking devices

Site Location (Winter Before Construction)

Early Project Work

- Trenching & Excavation
- Horizontal SAAs and EPCs installed
- Posts for AMTS and solar panels were drilled
- Cabinet Hardware + Sensor Conduit + Cabling





Beginning Wall Block Placement

Horizontal SAA and Earth Pressure Cells are Installed and Acquiring Data

AMTS System: Targets Placed as Wall Progresses

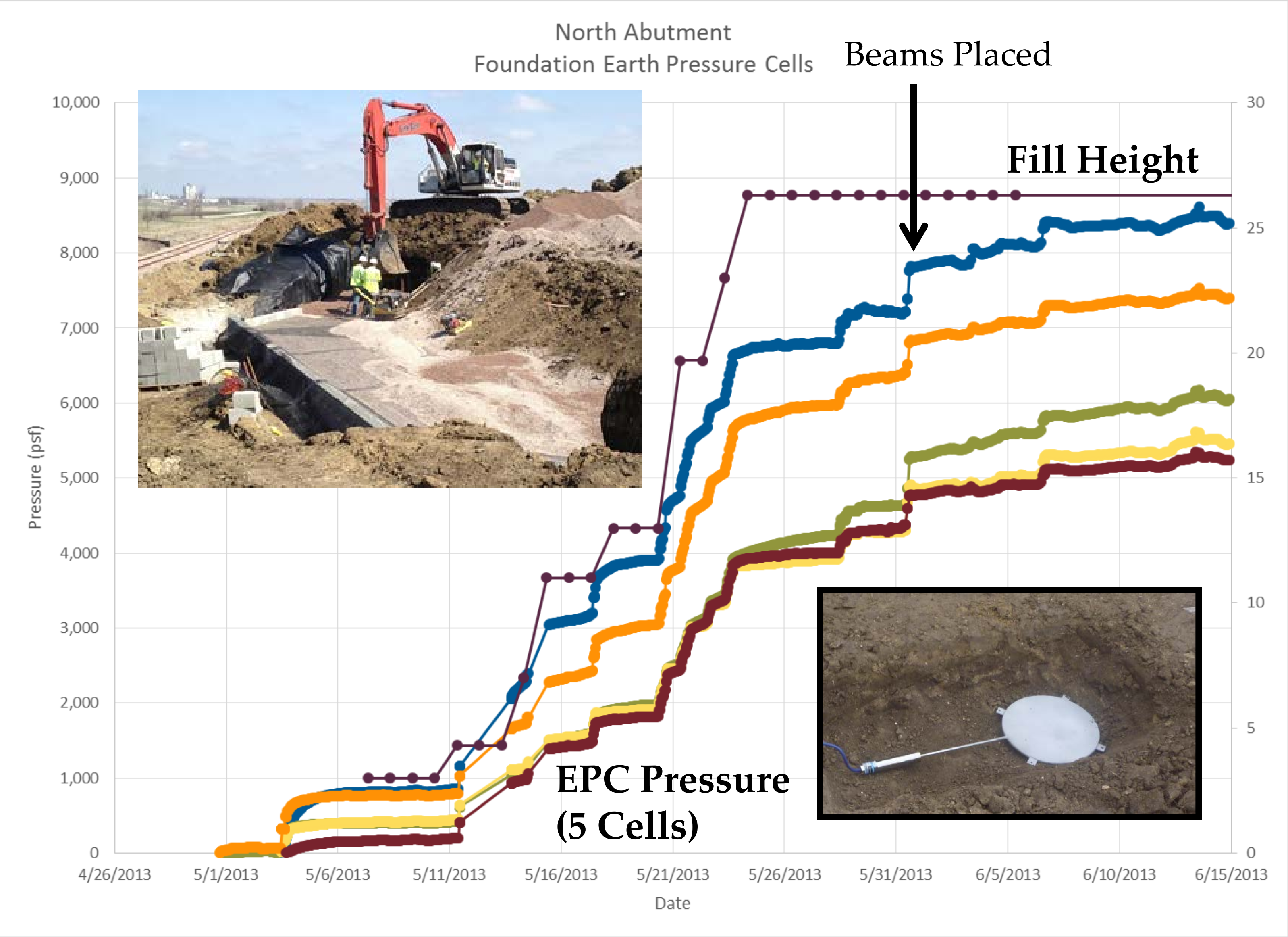

Some targets will be buried after initial construction

Vertical Wall Deformation and Beam Pressure

- SAA installed about 3′ from edge of box beams
- Installed after backfill is placed up to beams
  - Access available for rig and full wall height established
- June 4, 2013 (compare to AMTS target data from mid-May)
- 3 Fat Back EPC sensors installed on box beams (each end)

Finished Bridge Rail and Roadway Paving

North Abutment Construction Pressure/Fill

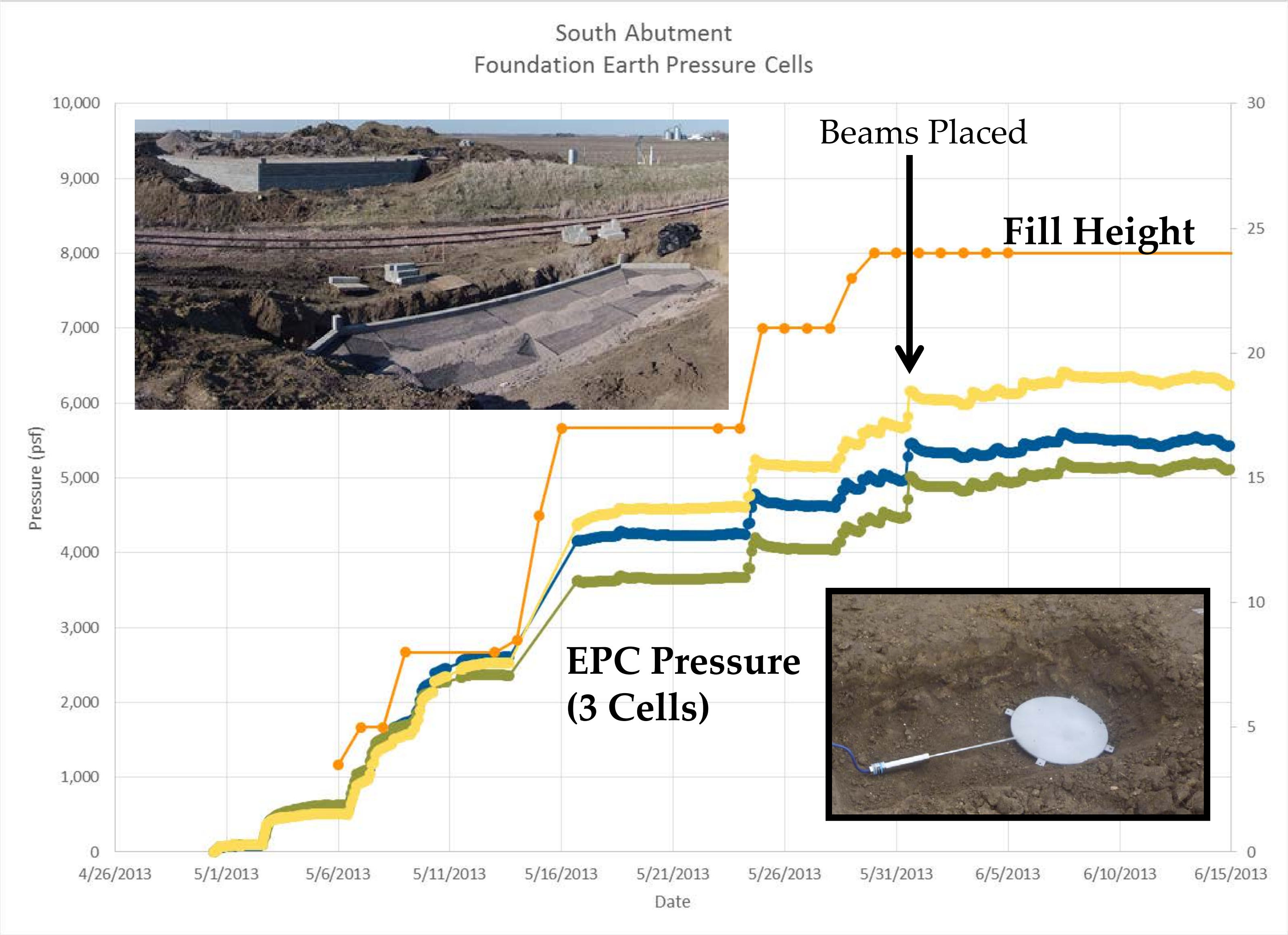


Beams Placed

Fill Height

EPC Pressure (5 Cells)

South Abutment Construction: Pressure/Fill

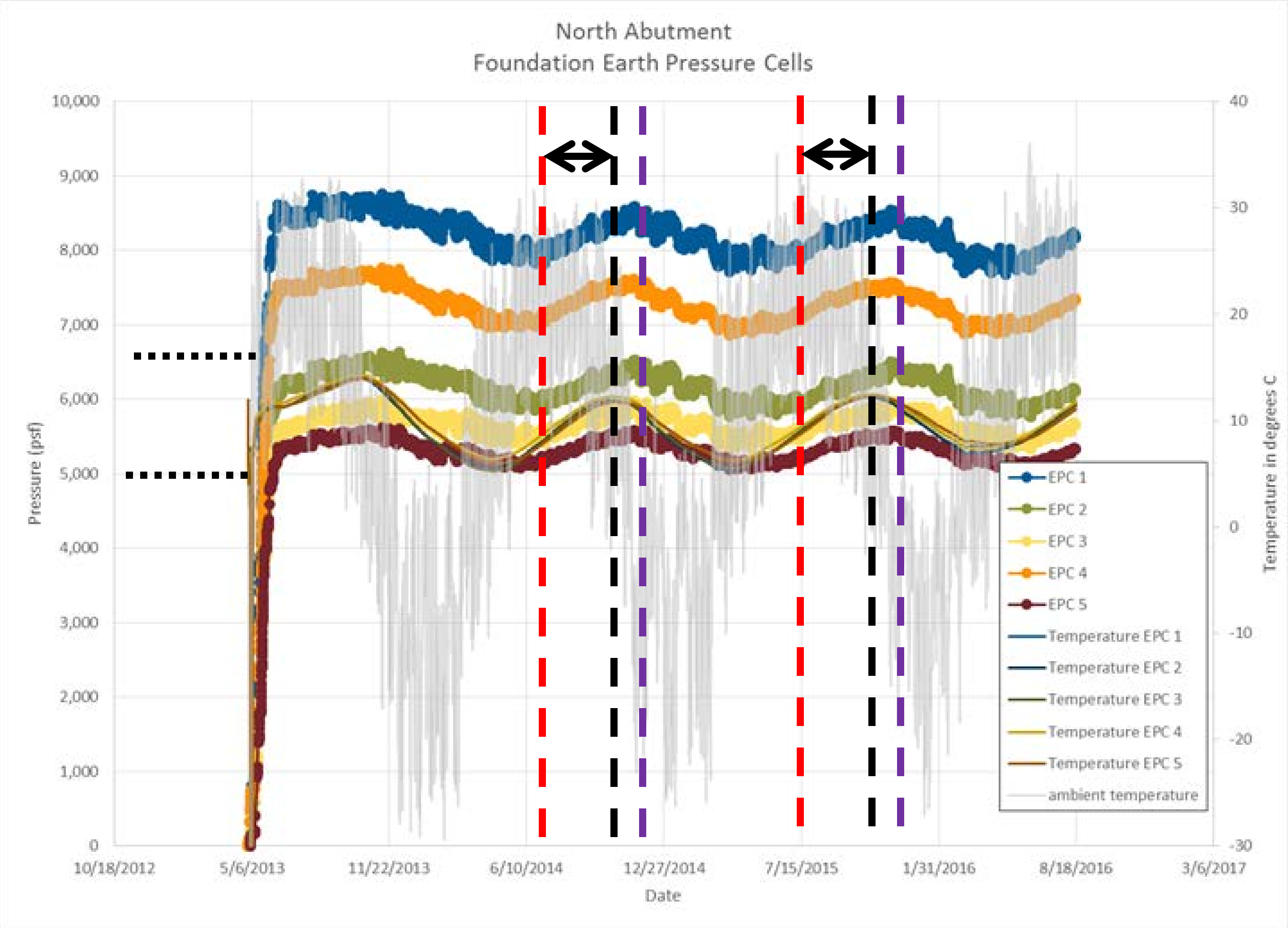


Beams Placed

Fill Height

EPC Pressure (3 Cells)

North Abutment Long-Term Earth Pressure



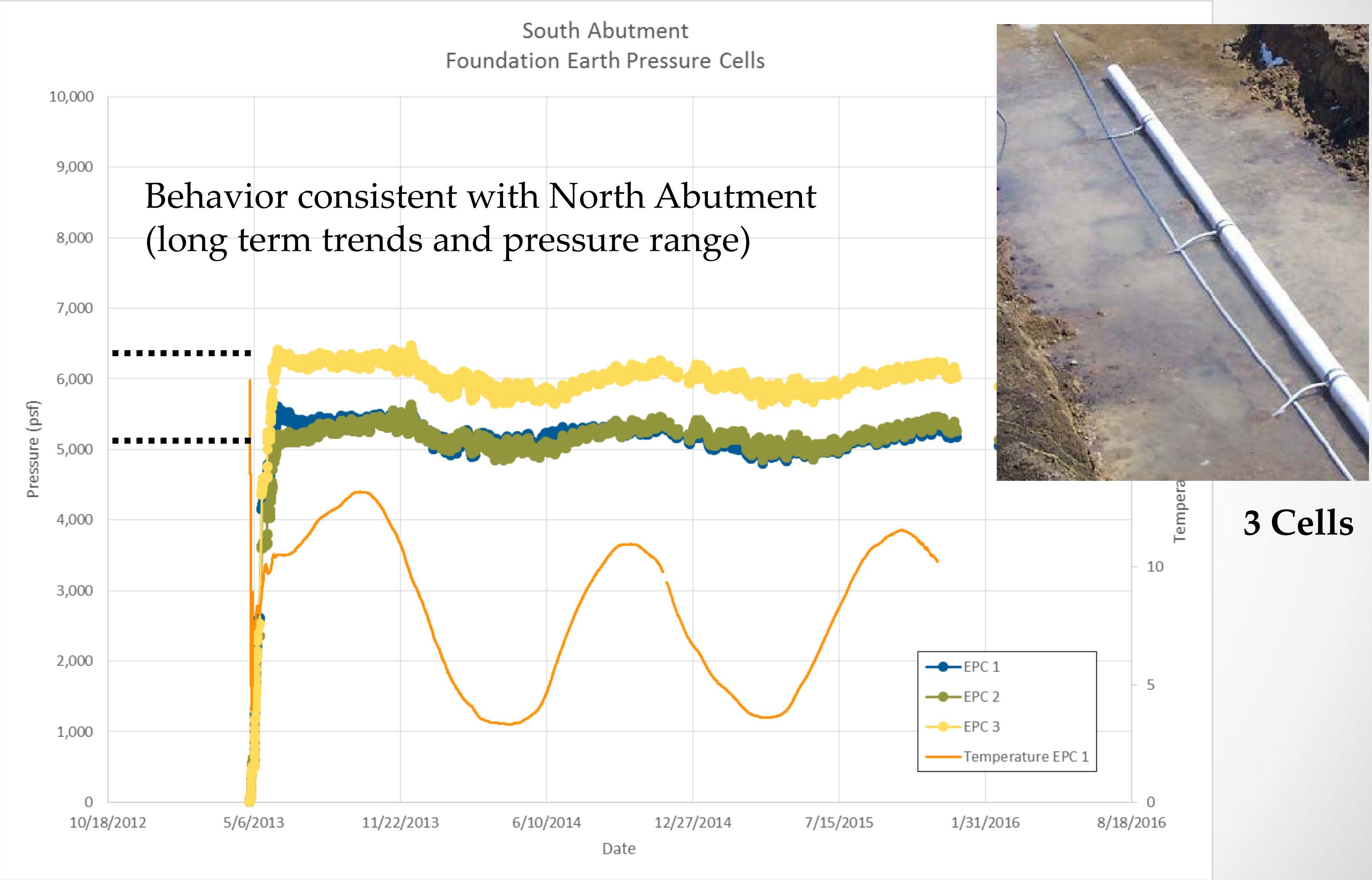
5 Cells

Ambient Temp. Peak

EPC Temp. Peak

EPC Max Pressure

South Abutment Long-Term Earth Pressure

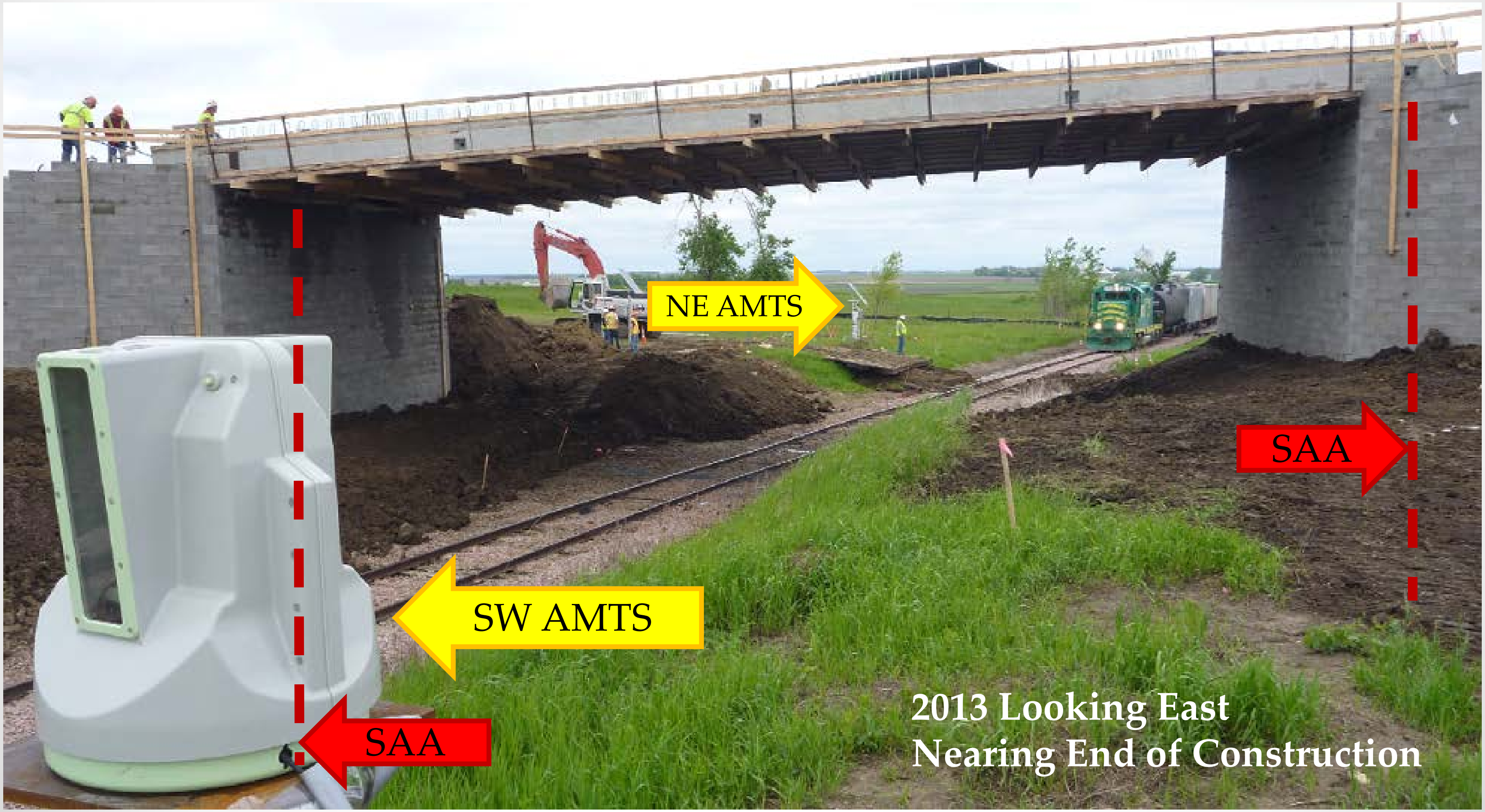


Behavior consistent with North Abutment (long term trends and pressure range)

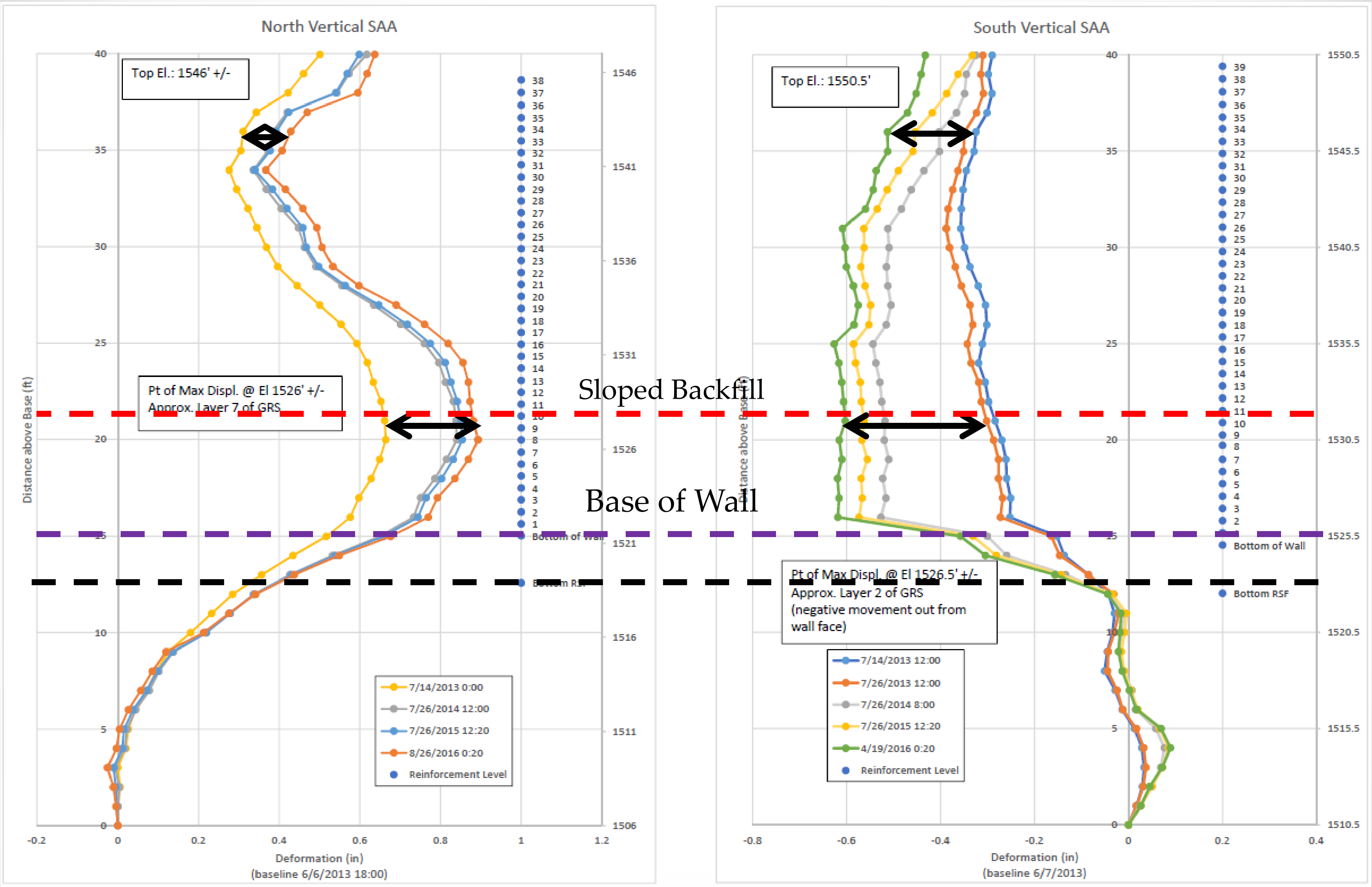
3 Cells

Lateral (N/S) Wall Deflection Measurements:

AMTS (scanning center and east/west wing wall faces: 60+ optical prism targets)
Vertical SAA sensors at center of both abutments

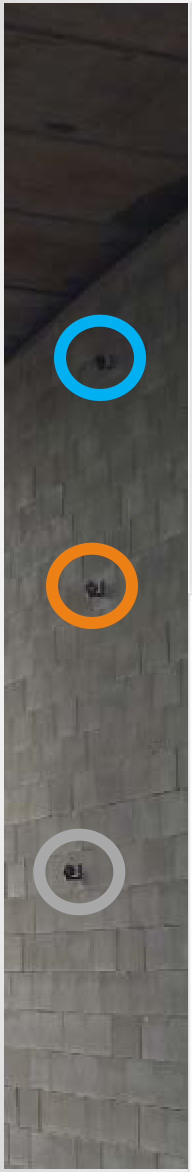


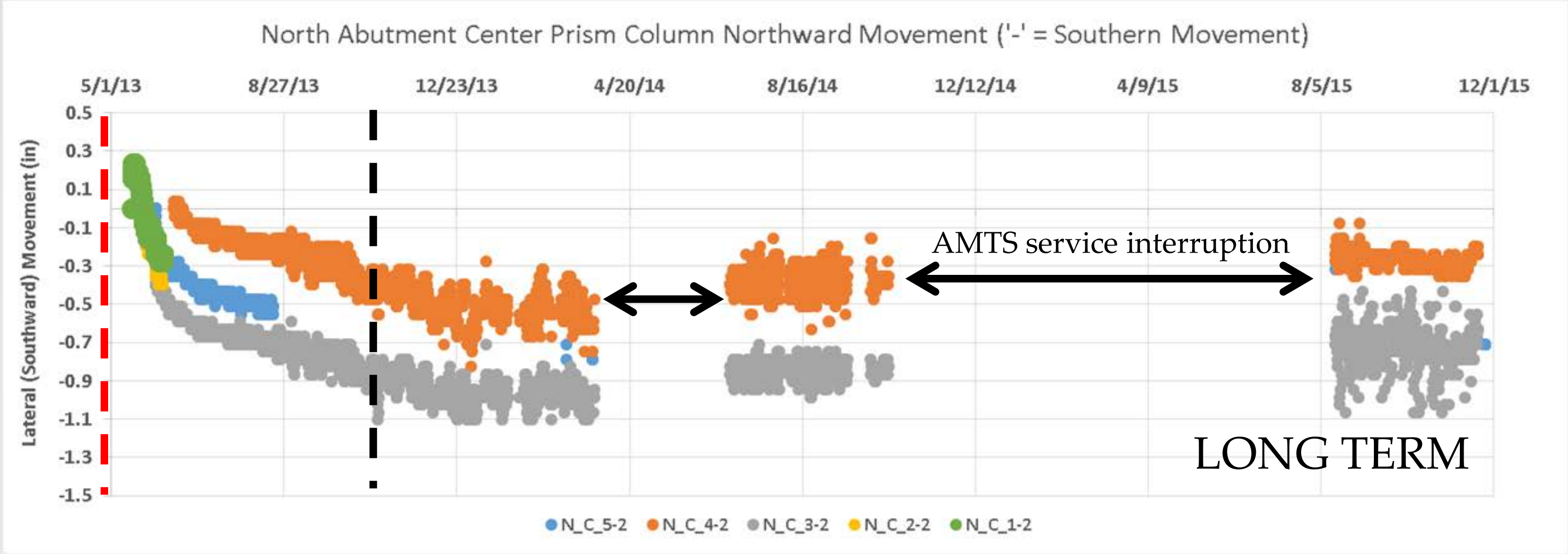
Vertical Wall Deformation 2013-2016



- Largest movements at the lower portion of the wall above embedded portion

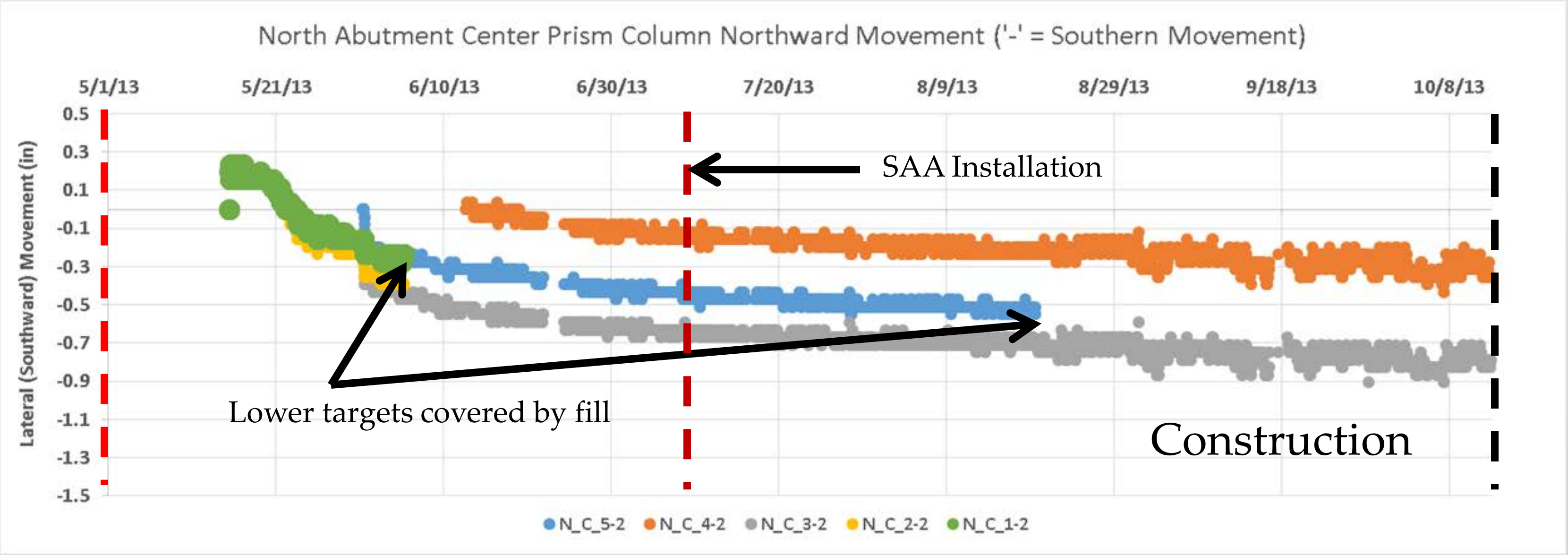
North Abutment Translation: (-0.2” to -0.9”N)




North Abutment Center Prism Column Northward Movement ('-' = Southern Movement)

AMTS service interruption

LONG TERM

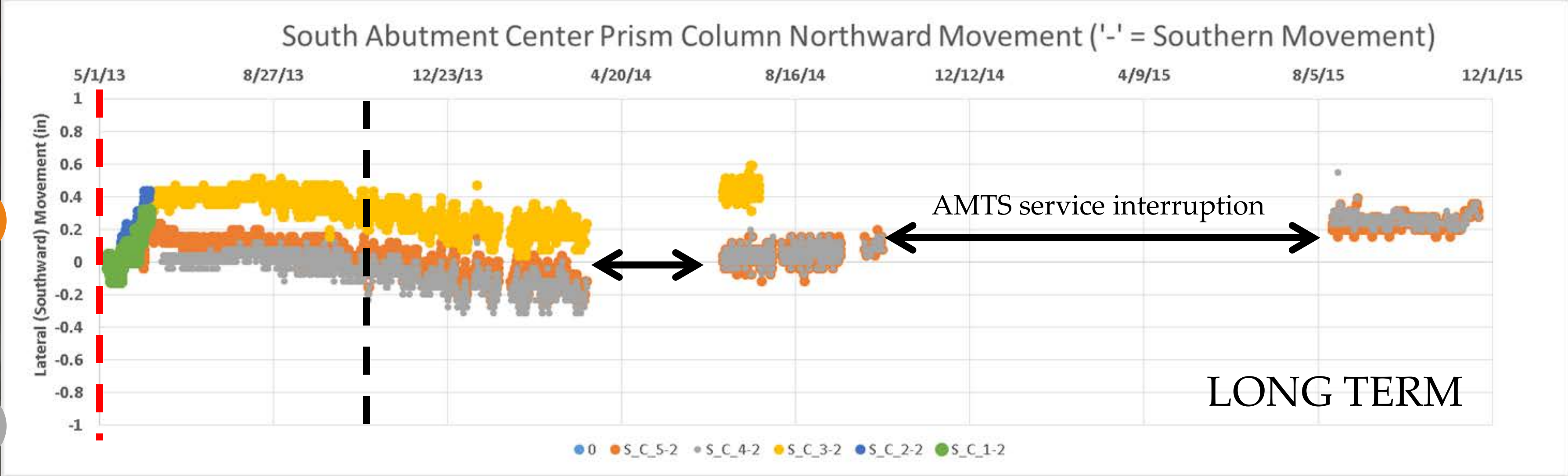

North Abutment Center Prism Column Northward Movement ('-' = Southern Movement)

SAA Installation

Lower targets covered by fill

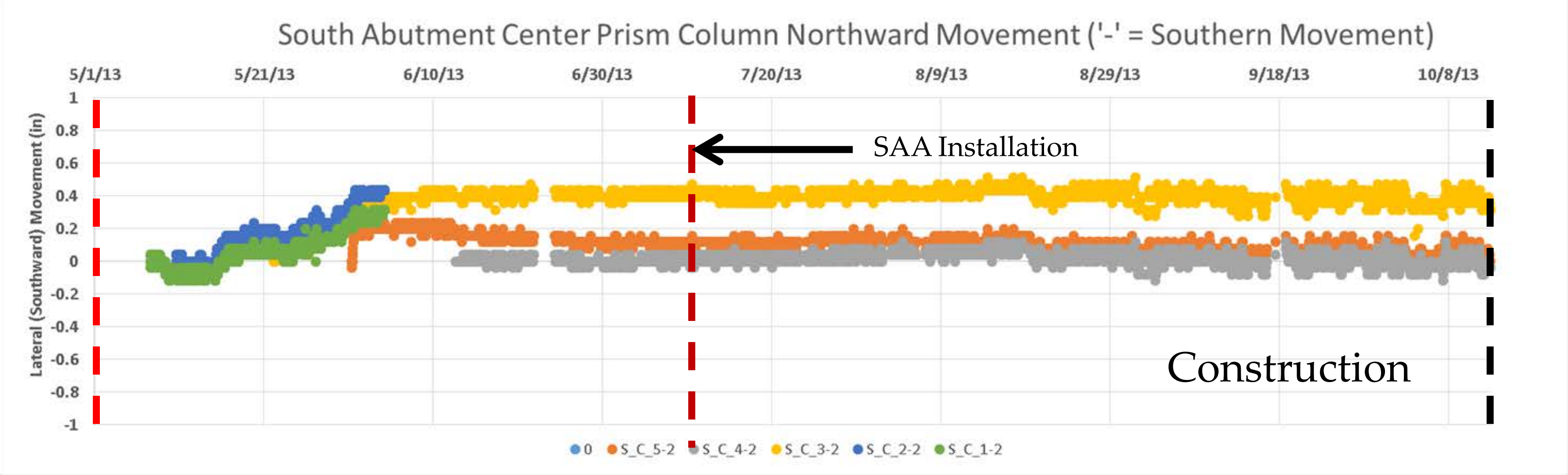
Construction

South Abutment Translation : (-0.2" to 0.4"N)


South Abutment Center Prism Column Northward Movement ('-' = Southern Movement)

AMTS service interruption

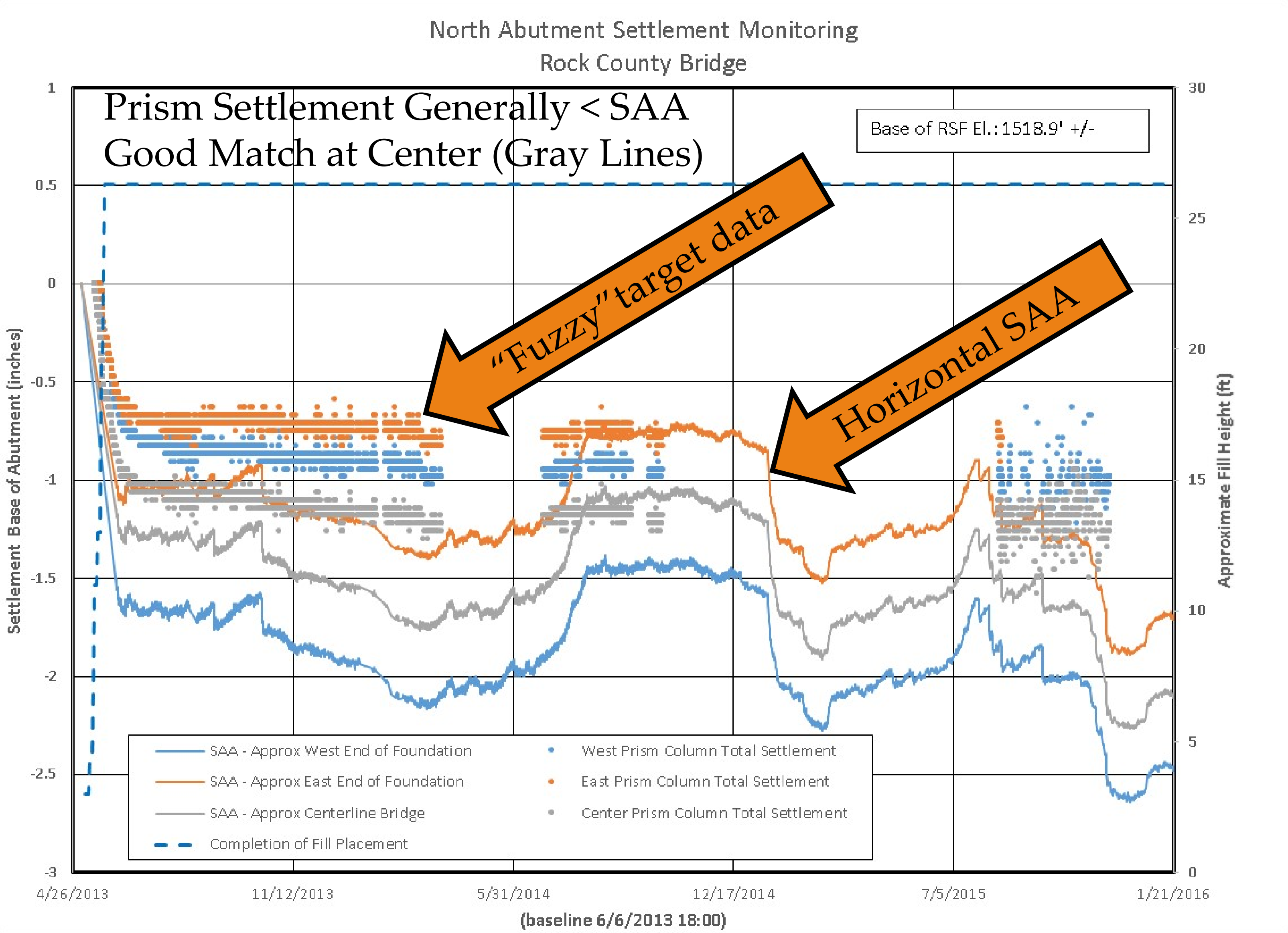
LONG TERM


South Abutment Center Prism Column Northward Movement ('-' = Southern Movement)

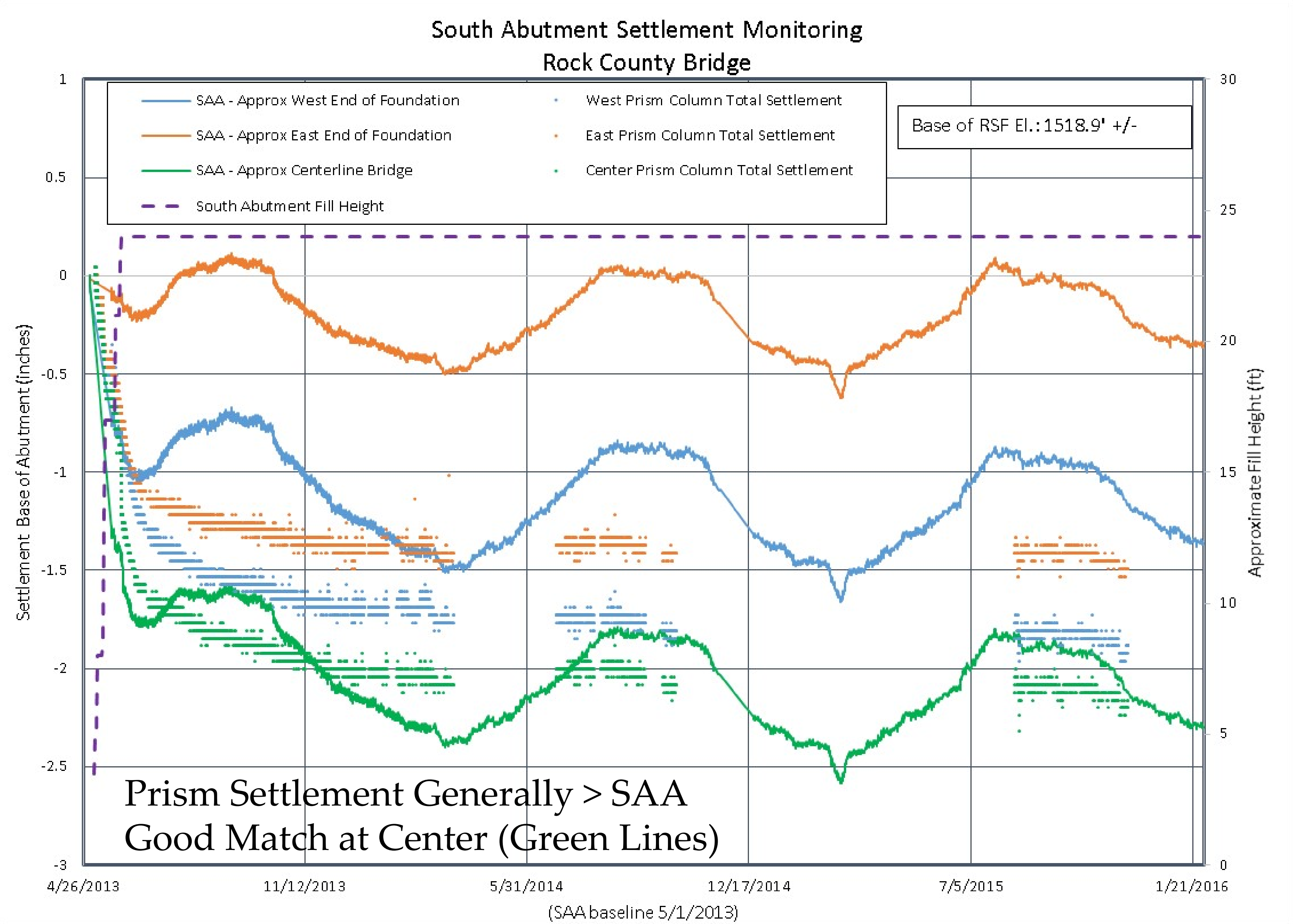
SAA Installation

Construction

North SAA + Prism Settlement



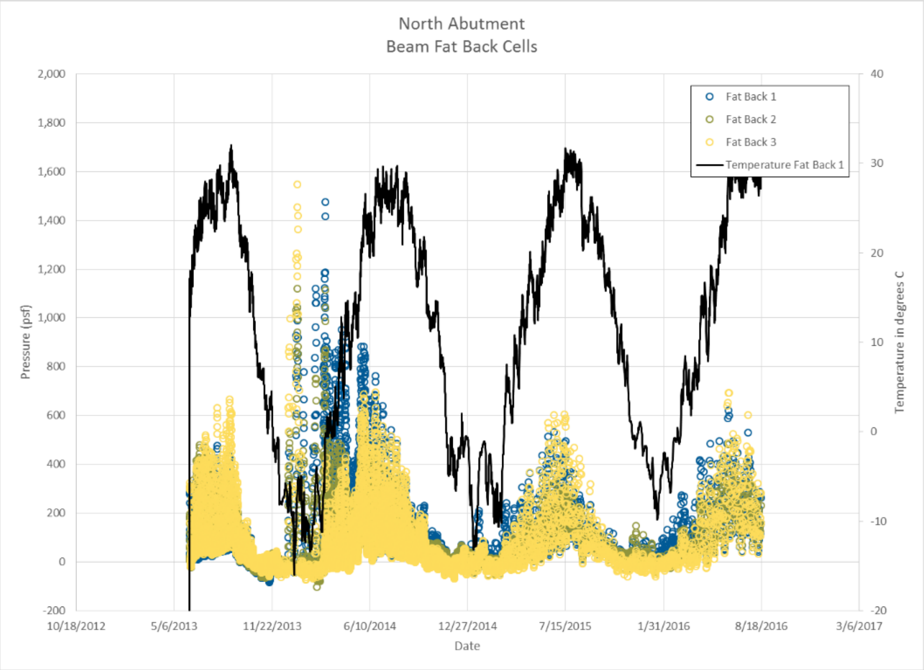
South SAA + Prism Settlement

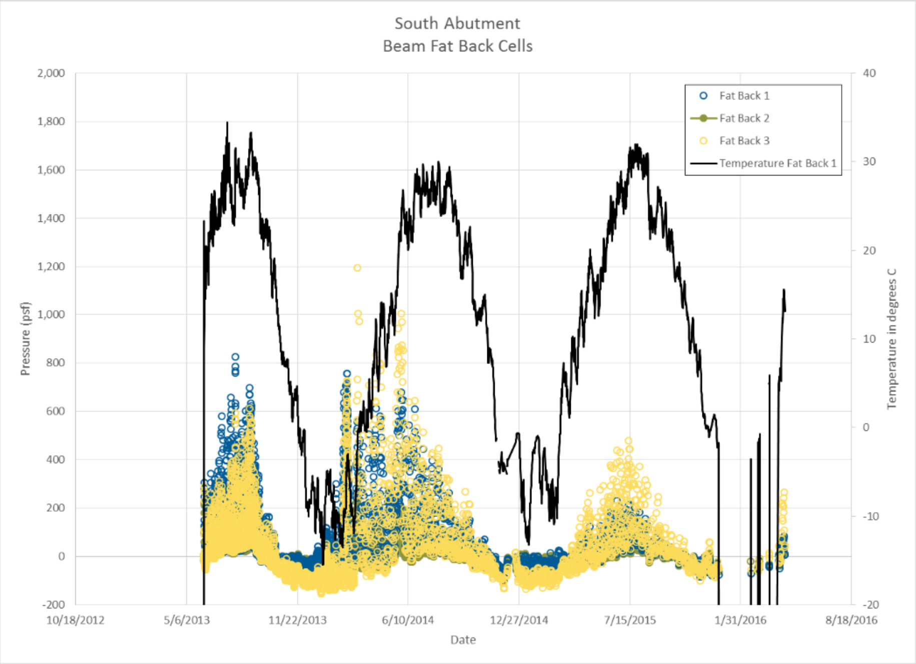


Prism Settlement Generally > SAA
Good Match at Center (Green Lines)

Abutment Beam EPC Response 2013 - 2016

SOUTH ABUTMENT
(high side of bridge)





Sensor/Prism Monitoring Summary (2016)

- Lateral movement: -0.2 to 0.9 inch at both abutments
  - Larger movement at wall base (bulging)
  - Distinct short-term generally outward movements; longer-term creep movement
  - Behavior is different than rigid tilt (active pressure on retaining wall)
- Settlement: 0.5 to 2.0 inches at both abutments
  - Majority occurred during initial construction and backfilling (steep curve)
  - Several years of small magnitude creep appears to be present (shallow, long-term, curve)
  - Long-term settlement magnitude is minimal
  - Targets showed largest settlement at center of structure
- Base EPCs showed regular increase during construction
  - Show jumps when new loads are applied (fill/beams) some creep between loading events
- Earth pressure at beams was most dynamic sensor reading
  - large daily and seasonal temperature variations
- North EPC Beam Pressures (lower elevation) were somewhat higher than those observed at South side (higher elevation)

Monitoring Program Technical Support

Field problems were both technical and rodent-based*

*Field mice (south system cabinet) snacked on antenna wiring

Performance Monitoring and Instrumentation Challenges

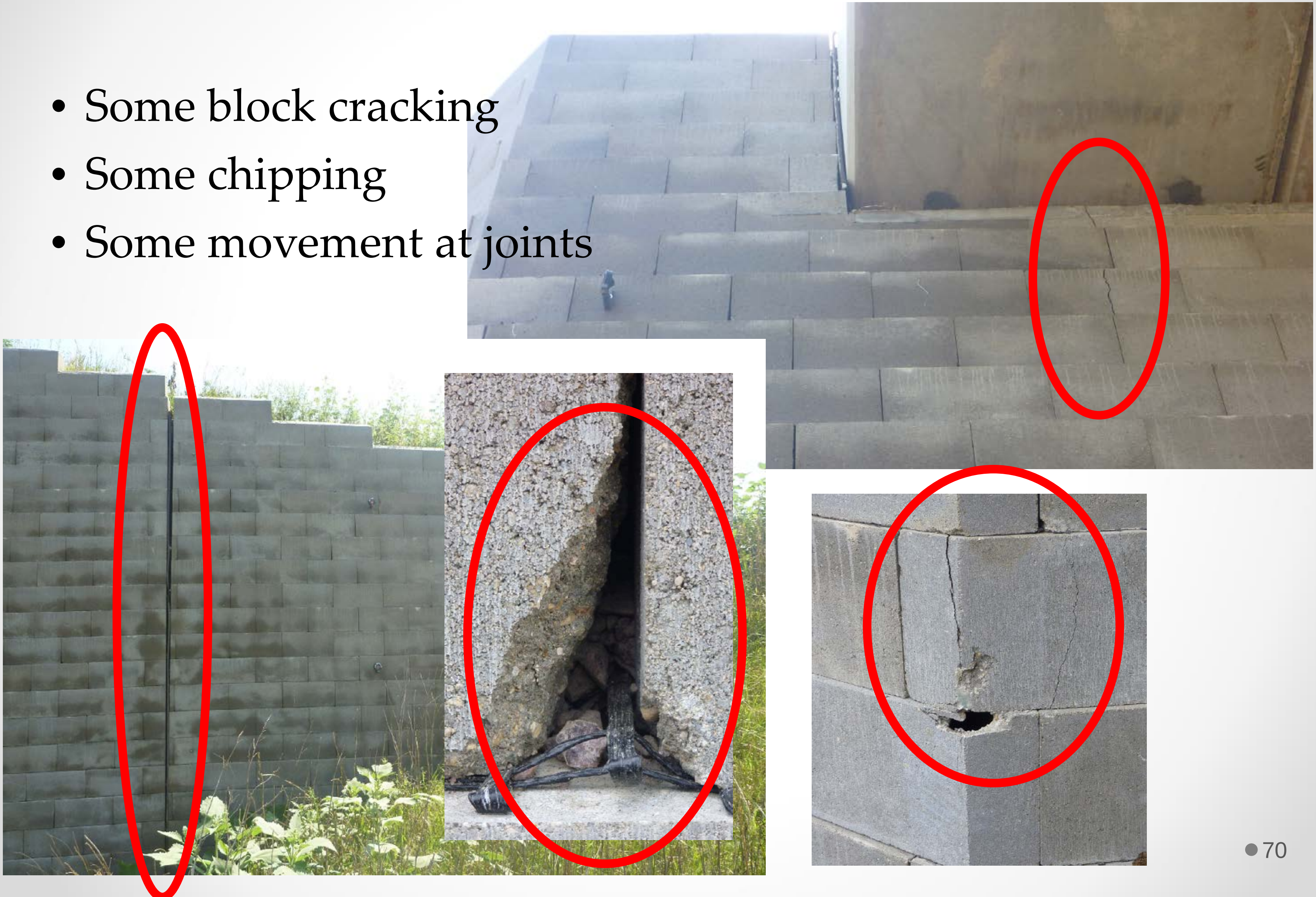
- Coordination: Several different crews installed site sensors
- Remote site location (4.5 hours from Twin Cities)
- Power and Communications (radio + cellular modem)
- Correlation of data from instruments installed at different times and loading points during construction sequence
- Large amounts of data/frequency could have been reduced
  - Intermittent construction activity made this somewhat challenging
  - Data presentation (different sensor installation start times, additive movement)
- Very small movements are very difficult to measure*
  - Fixed datum is required- often hard to come by at a construction site
- *Temperature effects on equipment and data
- Several types of error associated with different sensors

Bridge In Service (looking west)

A summary of technical, measured, performance has been discussed

Qualitative Fascia Distress

- Some block cracking
- Some chipping
- Some movement at joints



Pavement Cracks (2016 Observations)

- Distinct, uniform, crack in pavement at beam ends

3 Year Project Study Conclusions

- No significant movement appears related to the 5.3% grade of the bridge- distortions are 0.5” to 2.0”
  - Movements toward the south (high side) appear comparatively large
  - Wall movement is complex and appears to include aspects of settlement (both initial and creep), bulging, tilt/rotation, and translation
  - Movements are small; temperature effects are comparatively large
- Distress is present in pavement and some blocks
  - Pavement cracks observed across entire roadway at beam ends
  - Pavement cracks are the most noticeable performance feature
  - Small amounts of minor block distress- cracks, chips, gap at construction joint
- Studying performance is challenging
  - Maintaining AMTS systems required effort and many field trips
  - Power and cell modem issues arose several times during study
  - Project partners (design, construction, monitoring) did a great job

Acknoledgements

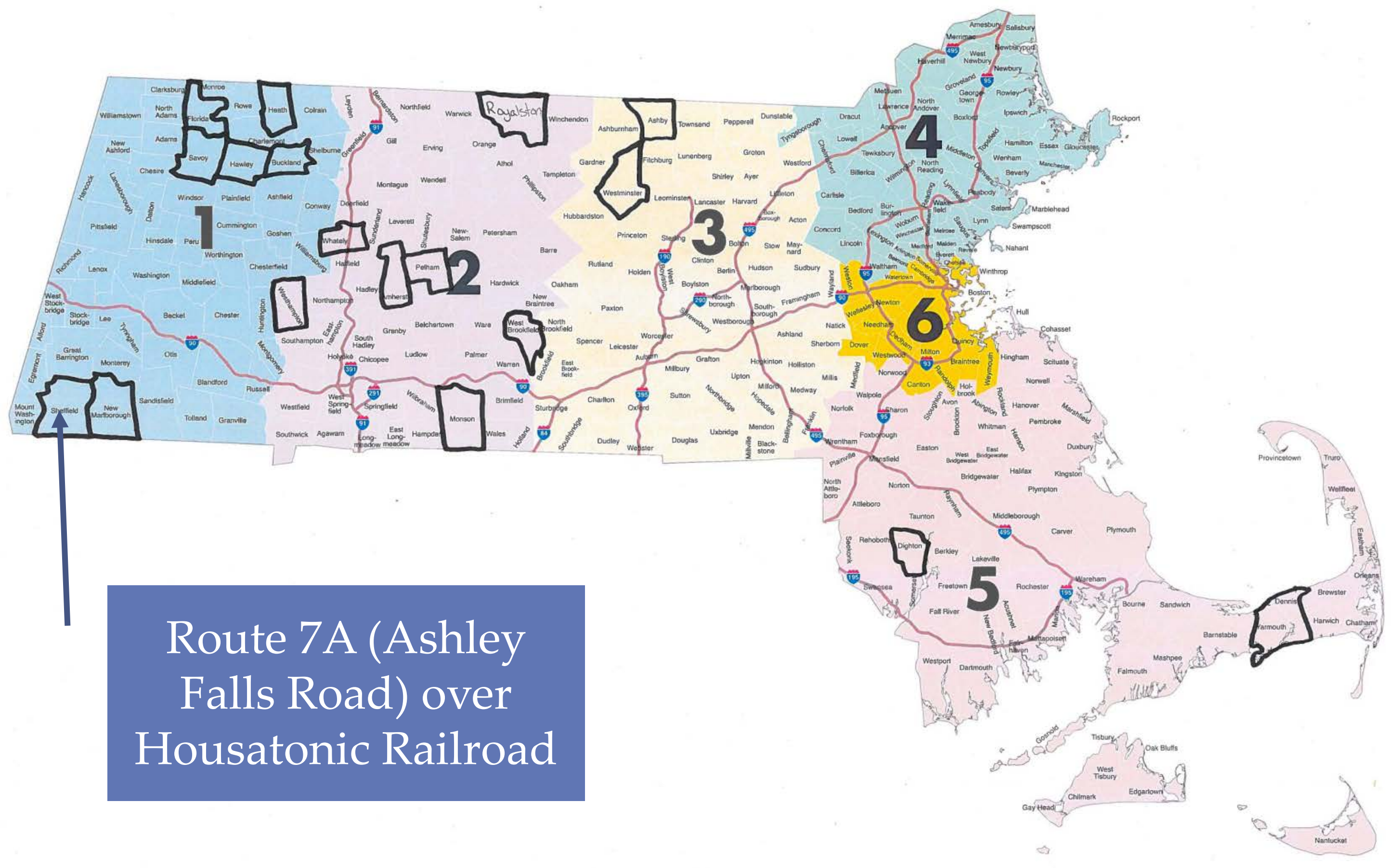
Special Thanks to:
Dan Mattison,
Joel Swenson,
Gene Bryant,
Aaron Grosser

END

RT 7A Over Housatonic RR (2014)

Peter Connors, P.E. – Massachusetts DOT

SHEFFIELD
Bridge No. S-10-023



Route 7A (Ashley Falls Road) over Housatonic Railroad

Sheffield S-10-023
Route 7A/Housatonic Railroad

Before

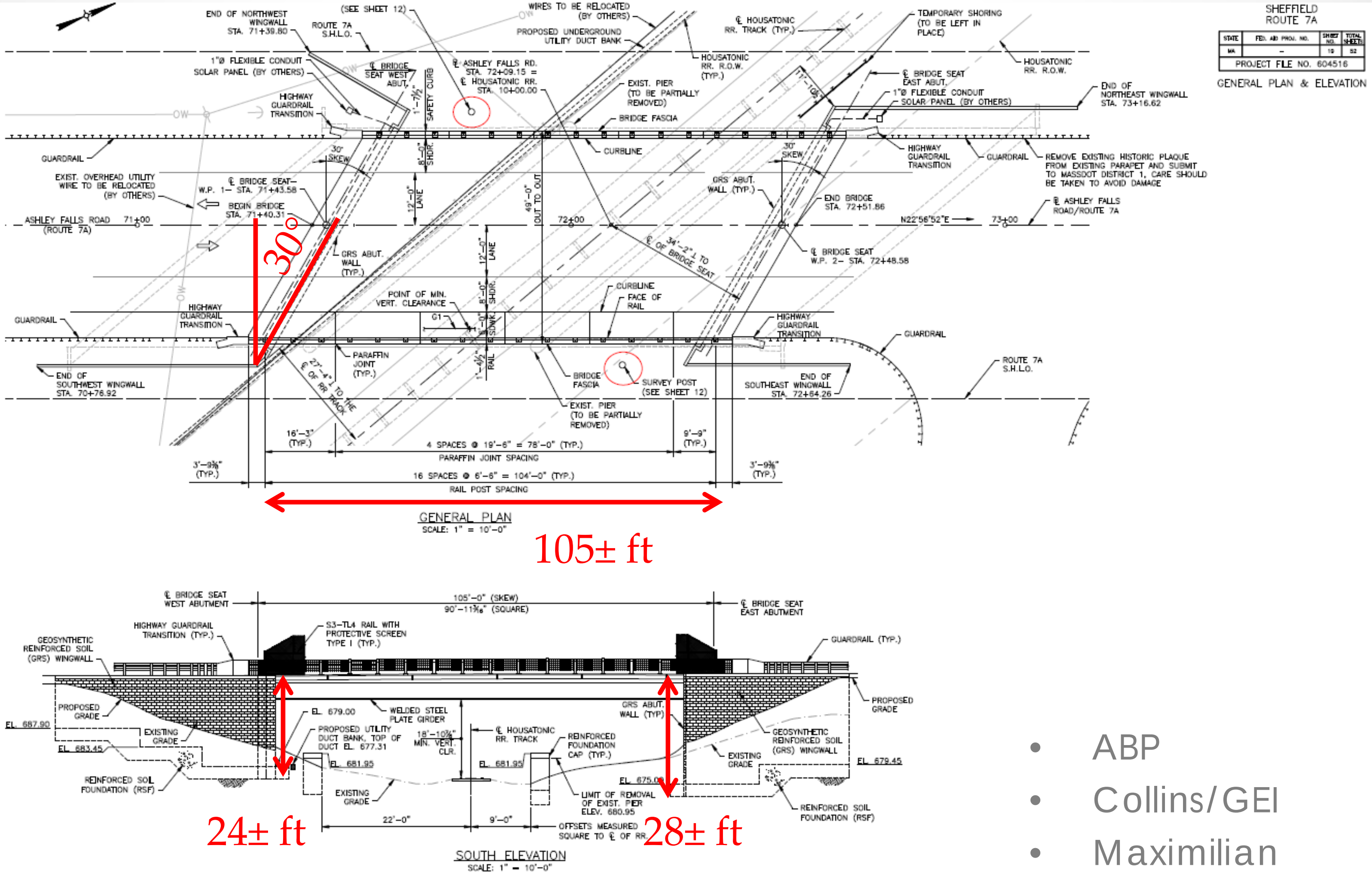
Built 1935

August 2016

Summary Details

- 105’ single span
- 30° skew
- 24’ to 28’ high walls (RR clearance)
- Steel girders w/ CIP deck
- Concrete footings for superstructure
- Cut down existing piers for RR protection
- FHWA instrumentation monitoring program
- 49% cost savings over original design!

Bridge Plan



- ABP
- Collins/GEI
- Maximilian
- District 1

Construction Timeline

- April to June, 2014 - GRS abutments built
- June - MassDOT showcase
- FHWA instrumentation
- July to August - beams set and cast back wall
- FHWA instrumentation
- September – CIP Deck
- October – Approaches and pavement
- November 18, 2014 – Complete and in service

GRS Construction

GRS Construction

- Standard CMU Blocks
- Woven Geotextile
- Open graded Fill (46-48° lab)

2014 Showcase

- 60 participants
- 1 day: class & site
- MassDOT Districts
- NE DOTs
- Local DPWs
- FHWA
- ACEC
- CIM

GRS Construction

Beams on footings

Crane loading

FHWA Instrumentation

- Installed by FHWA
- 36 months monitoring

- Soil Structure Interaction
- Response to 30° skew
- Compare to other GRS and traditional bridges

ASHLEY FALLS RD GRS-IBS - SHEFFIELD, MA

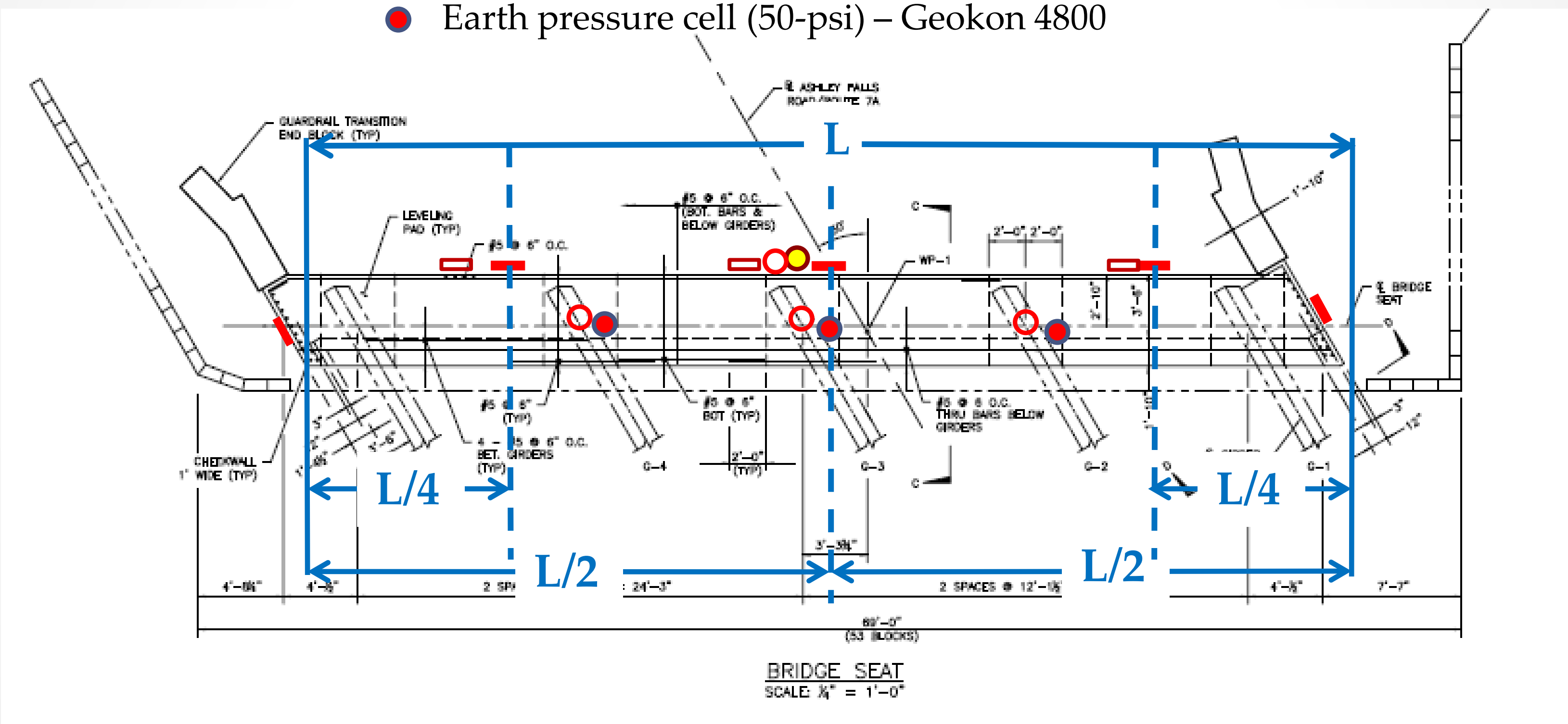
As-Built Layout of Instrumentation
Installed 6/2014 to 8/2014

As Built (both abutments)

○ ● In-place inclinometer casing (2.75 inch ID)

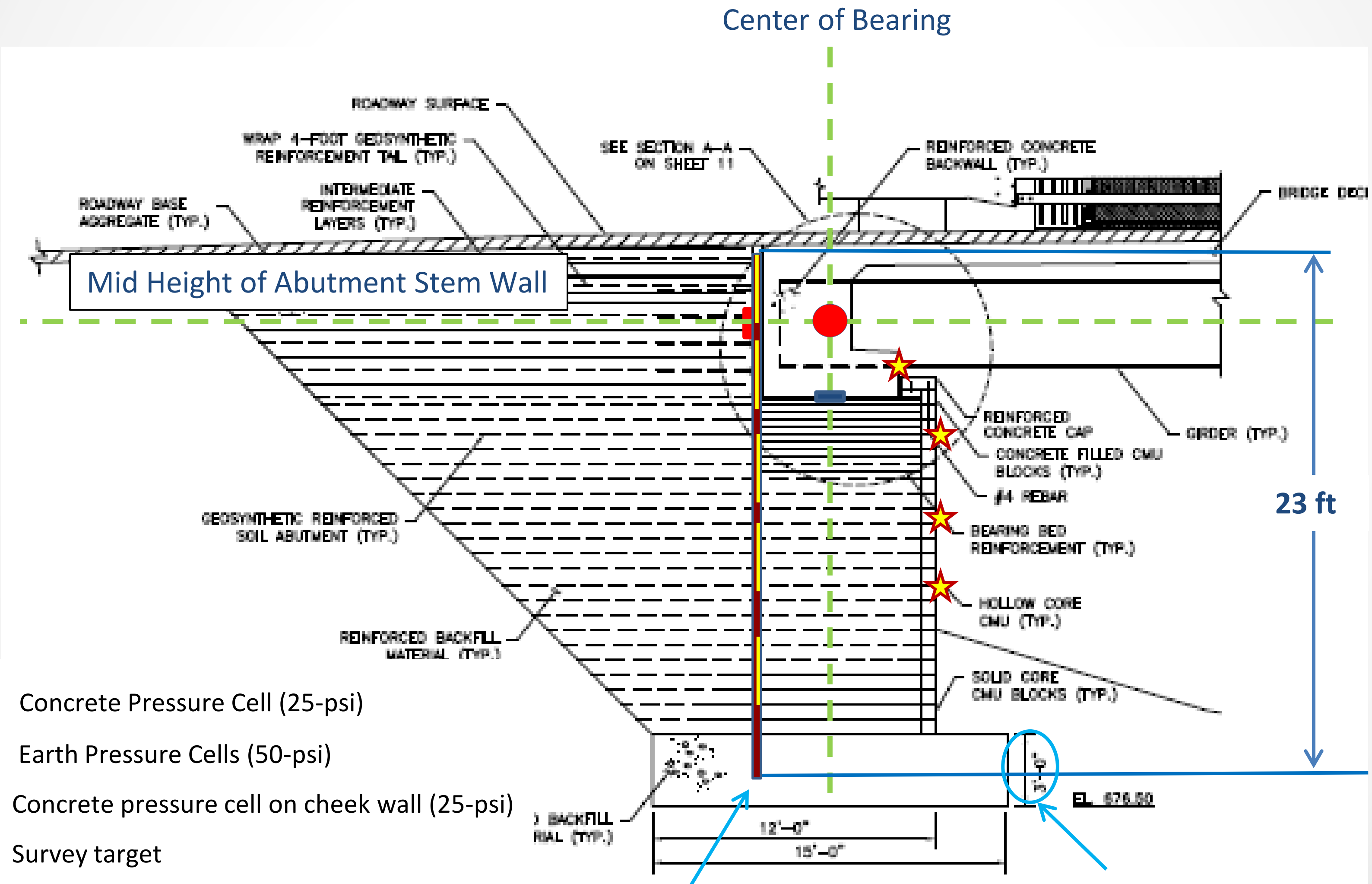
▯ ▮ Concrete(Fatback) Pressure Cell (25-psi) – Geokon 4810

● Earth pressure cell (50-psi) – Geokon 4800



Typical Instrumentation Layout for both abutments

West Abutment Instrumentation



🟥 Concrete Pressure Cell (25-psi)

▬ Earth Pressure Cells (50-psi)

● Concrete pressure cell on cheek wall (25-psi)

☆ Survey target

| In place inclinometer

Bottom of IPI casing embedded in bedrock ~1ft

RSF is 1.5 ft due to bedrock in excavation

Concrete Pressure Cells

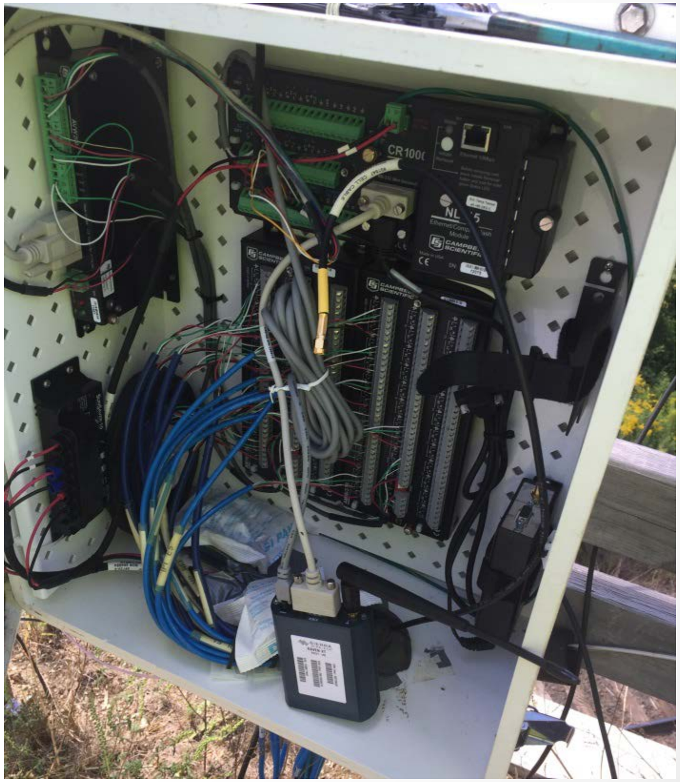
Stem Wall

Concrete Pressure Cells
Cheek Walls

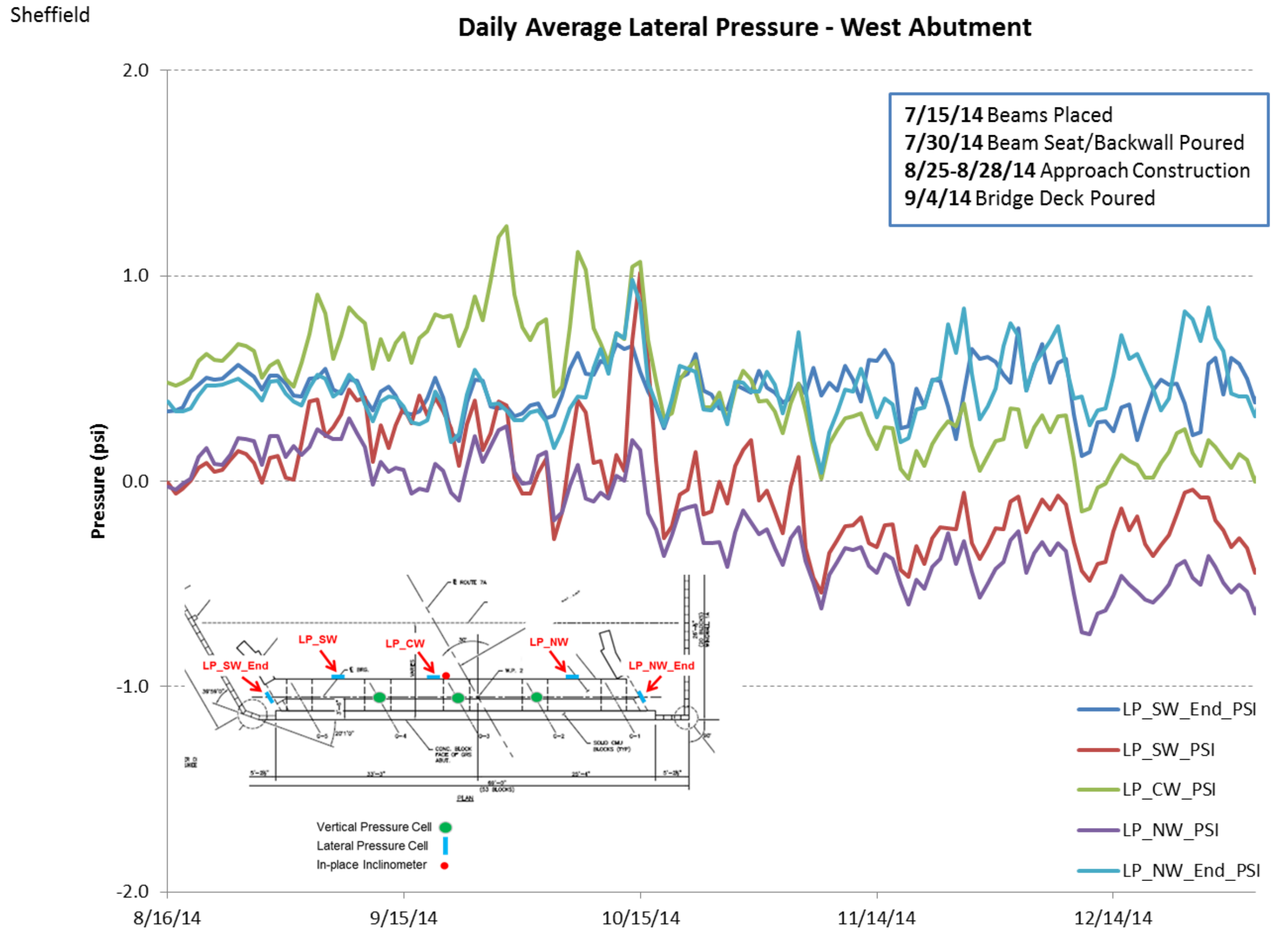
Instrumentation Panel

Battery Power from Solar

A/D Board and Modem



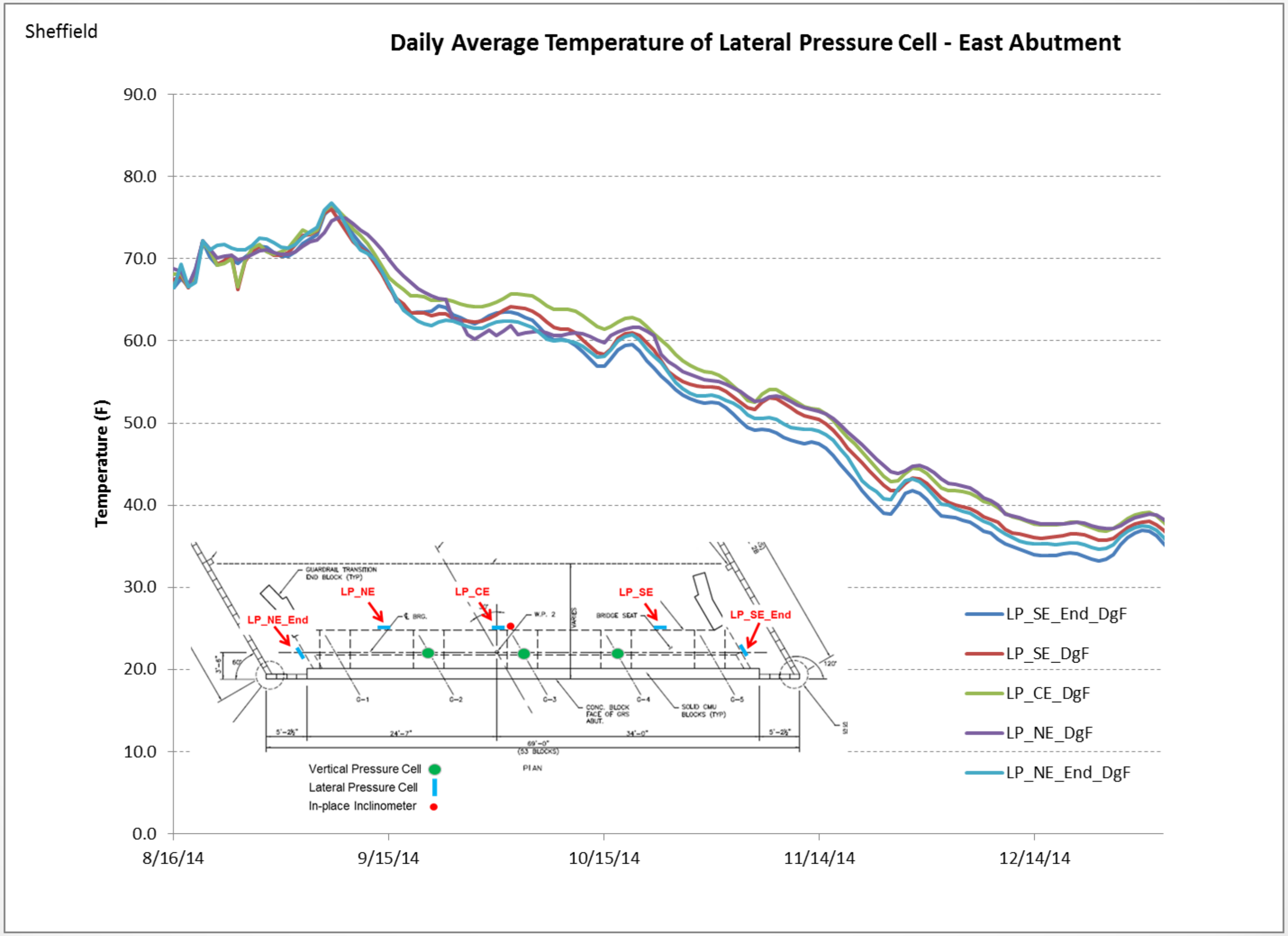
West Abutment Lateral Pressures


Sheffield

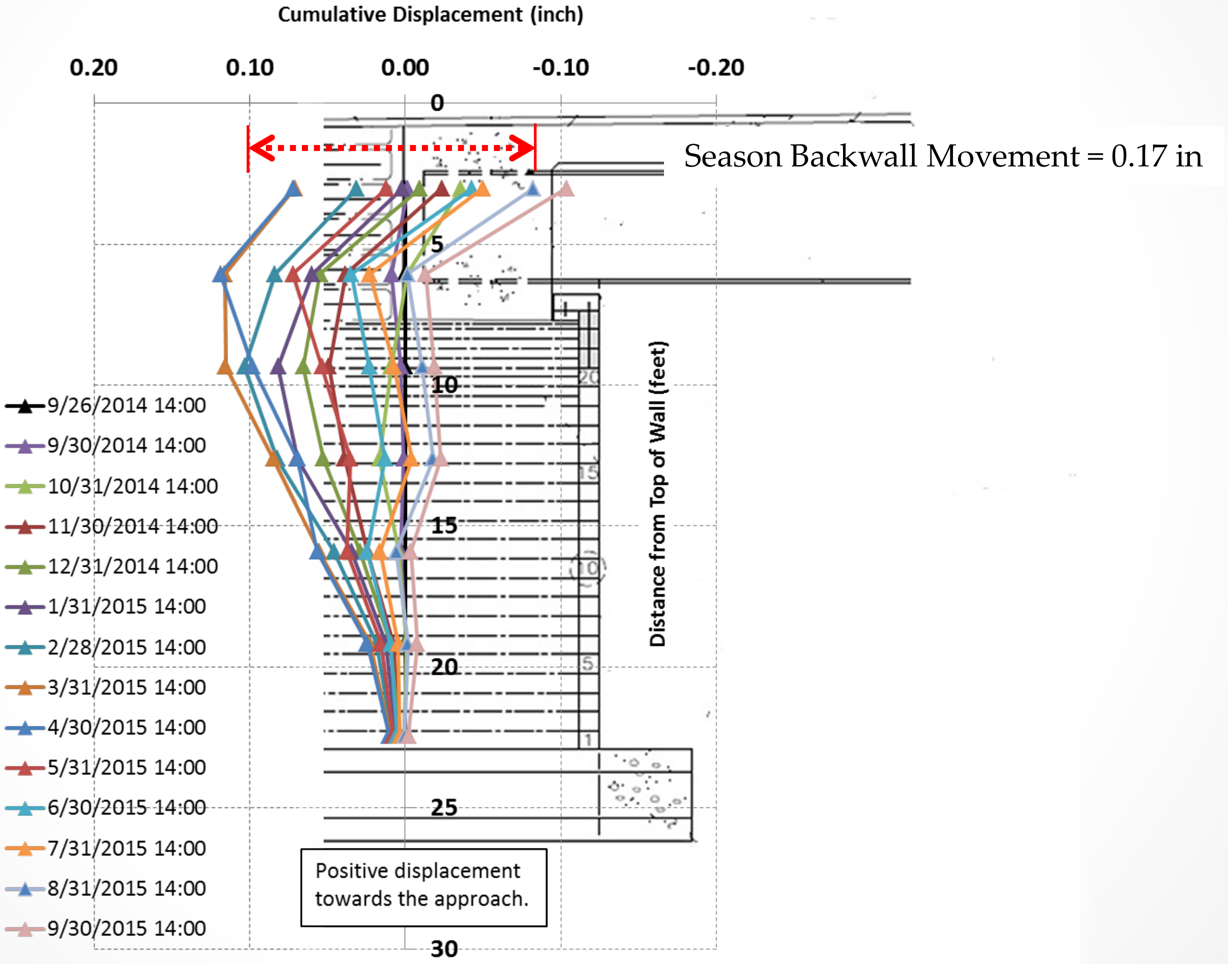
Daily Average Lateral Pressure - West Abutment

7/15/14 Beams Placed
7/30/14 Beam Seat/Backwall Poured
8/25-8/28/14 Approach Construction
9/4/14 Bridge Deck Poured

Daily Average Temperature
Pressure cells – East Abutment



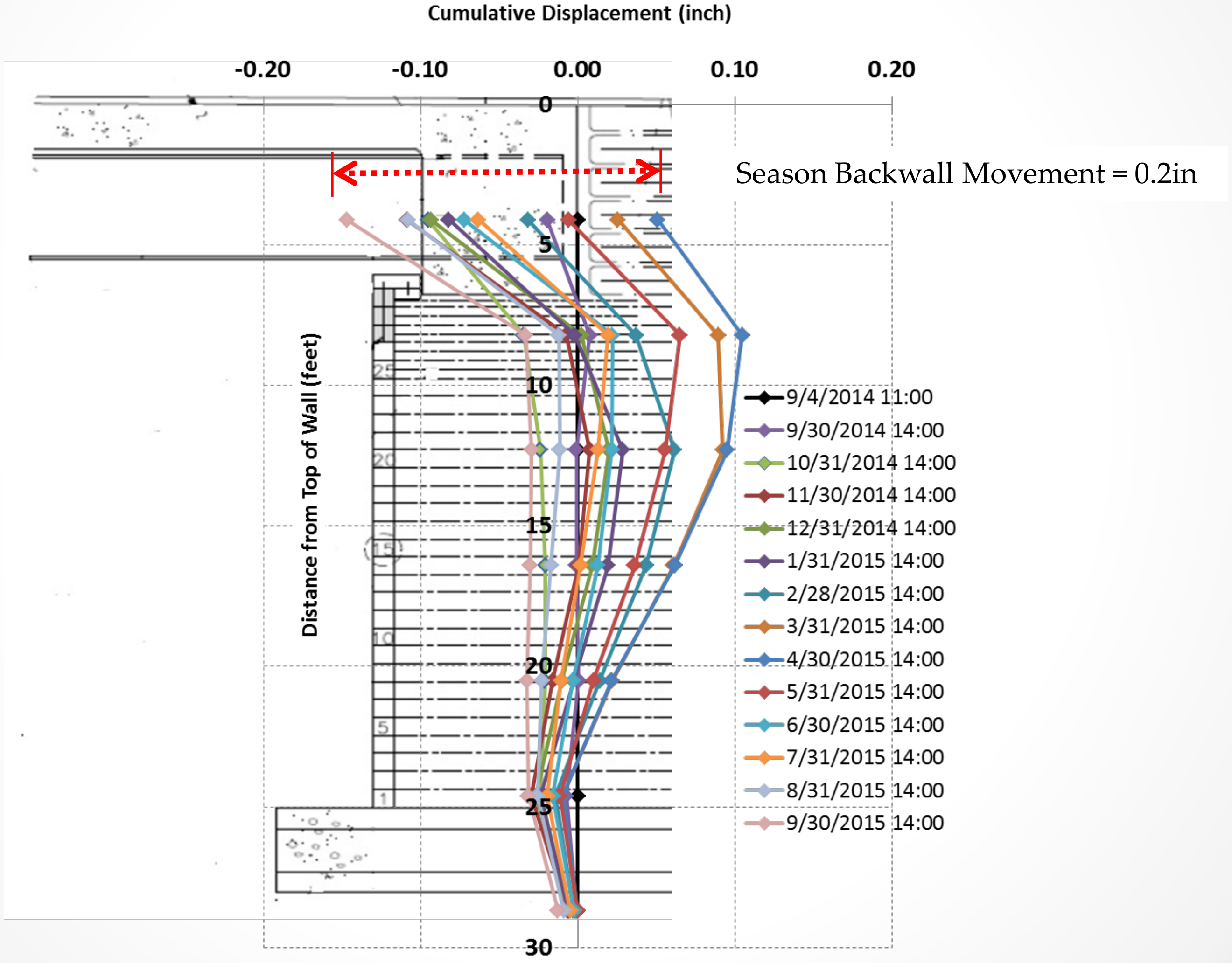
West Abutment In-Place Inclinometer



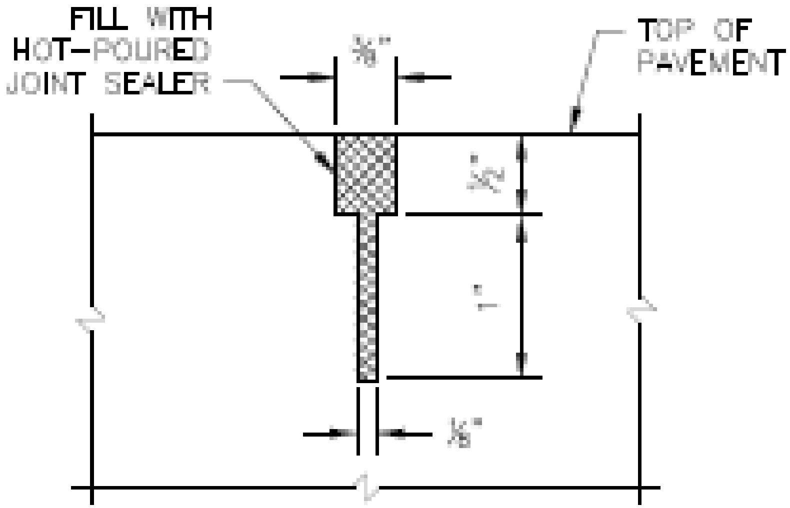
Season Backwall Movement = 0.17 in

Positive displacement towards the approach.

East Abutment In-Place Inclinometer



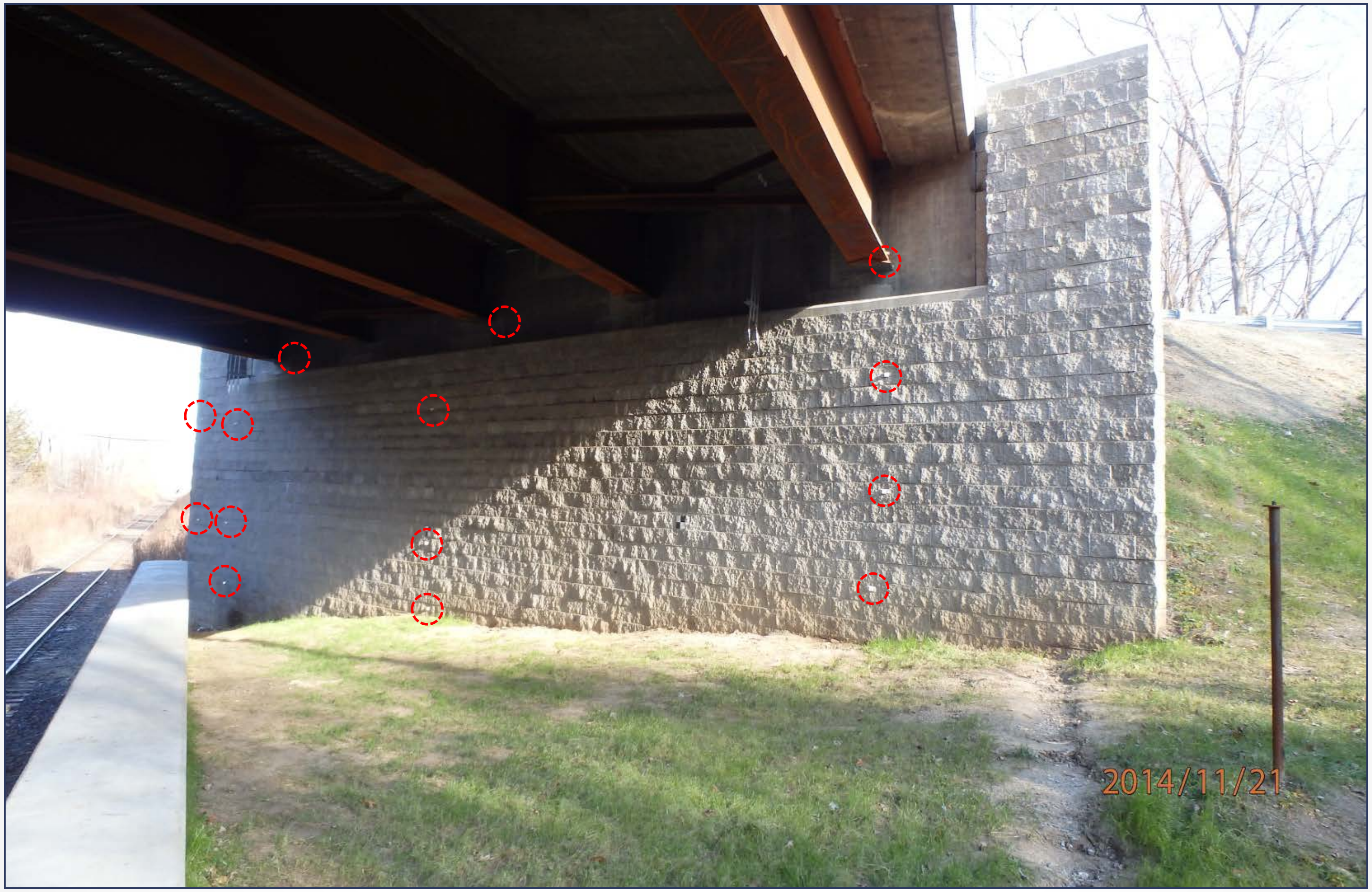
Pavement Sawcut



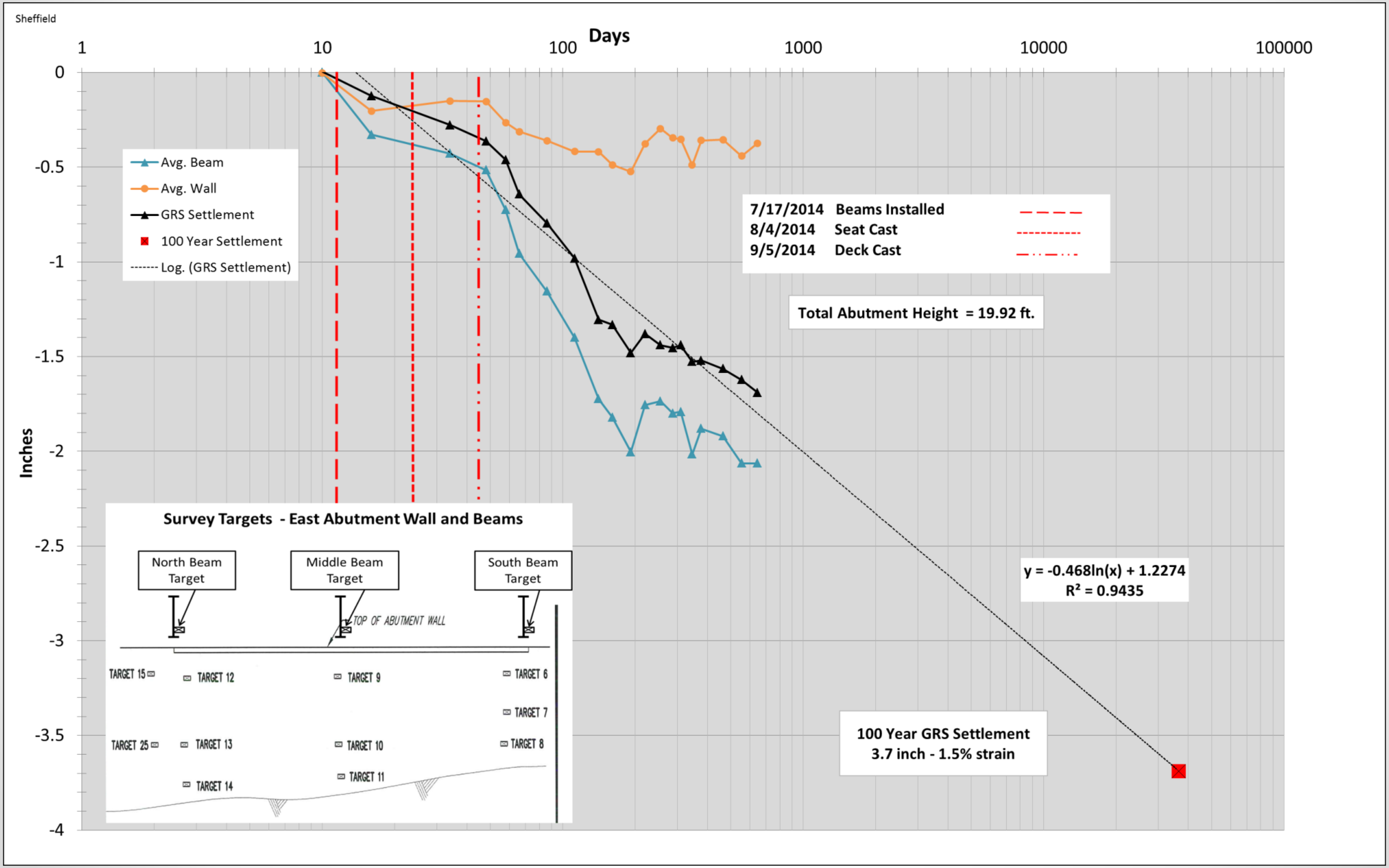
PAVEMENT SAWCUT

N.T.S.

Survey Targets for Settlement



East Abutment Survey Settlement



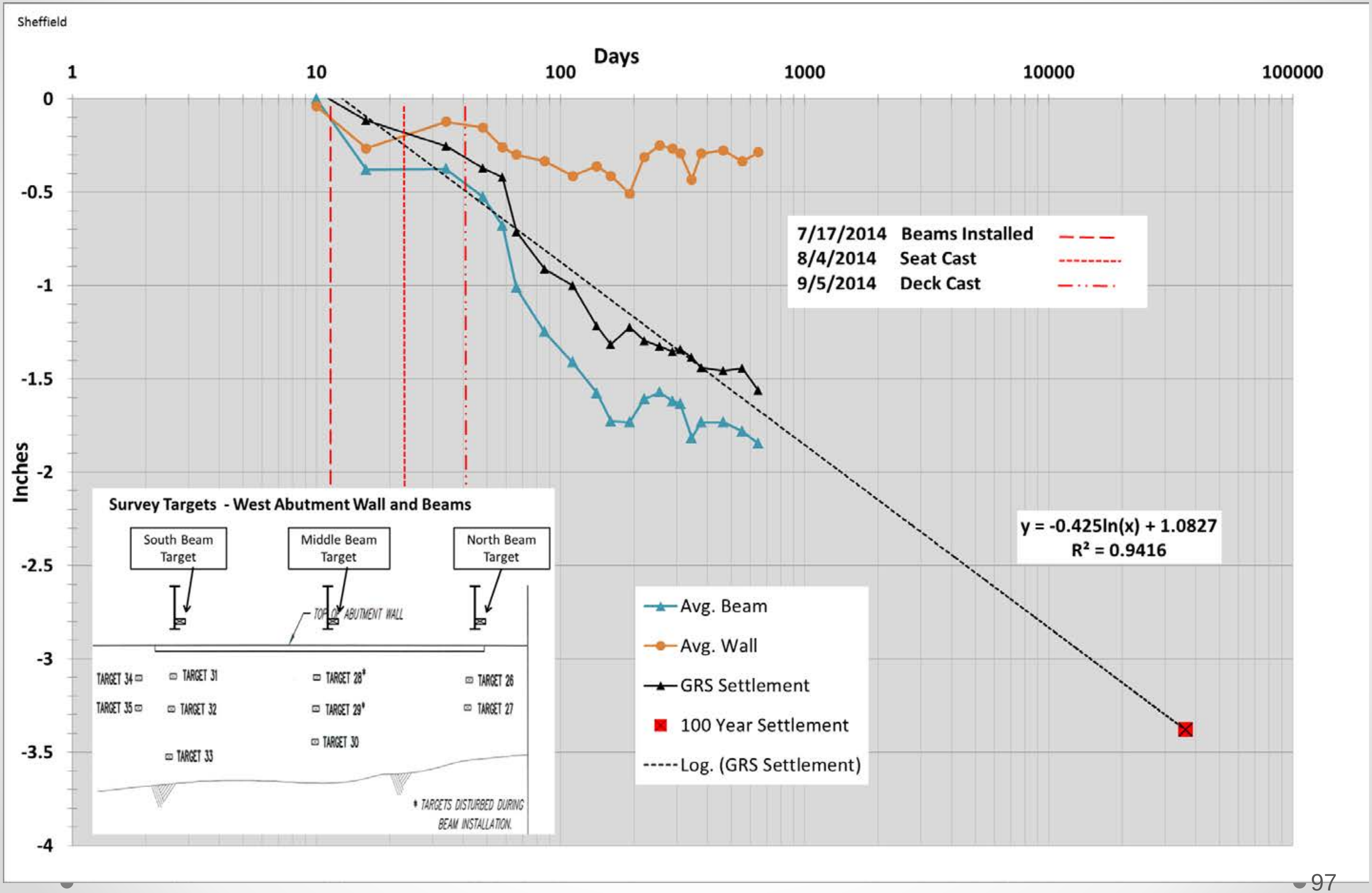
7/17/2014	Beams Installed	— — — —
8/4/2014	Seat Cast	------------
9/5/2014	Deck Cast	—·–·—·-·

Total Abutment Height = 19.92 ft.

$y = -0.468\ln(x) + 1.2274$
$R^2 = 0.9435$

100 Year GRS Settlement
3.7 inch - 1.5% strain

West Abutment Survey Settlement



Abutment Face 2016

Conclusions

- Monitoring ongoing
- Small longitudinal movements observed
- Horizontal Earth Pressure controlled by thermal effects
- GRS Settlement within FHWA guidelines

GRS IBS performance & deployment efforts

Daniel Alzamora, P.E. – *Federal Highway Administration*

Chesapeake City Road, DE (2013)

RT 7A Over Housatonic RR, MA (2014)

CR 55 over Minnesota Southern RR, MN (2013)

OH – Bowman Rd Bridge (2005)

OH – Tiffin River Bridge (2009)

HI – Kauaula Stream Bridge (2012)

WI – STH 40 Bloomer, WI (2012)

Project Example: UT – I-84 Echo Bridge (2013)

First GRS IBS on the Interstate; utilized SIBC

Constructed summer 2013

- No approach slab
- ADT > 8,000
- Truck ~ 40%

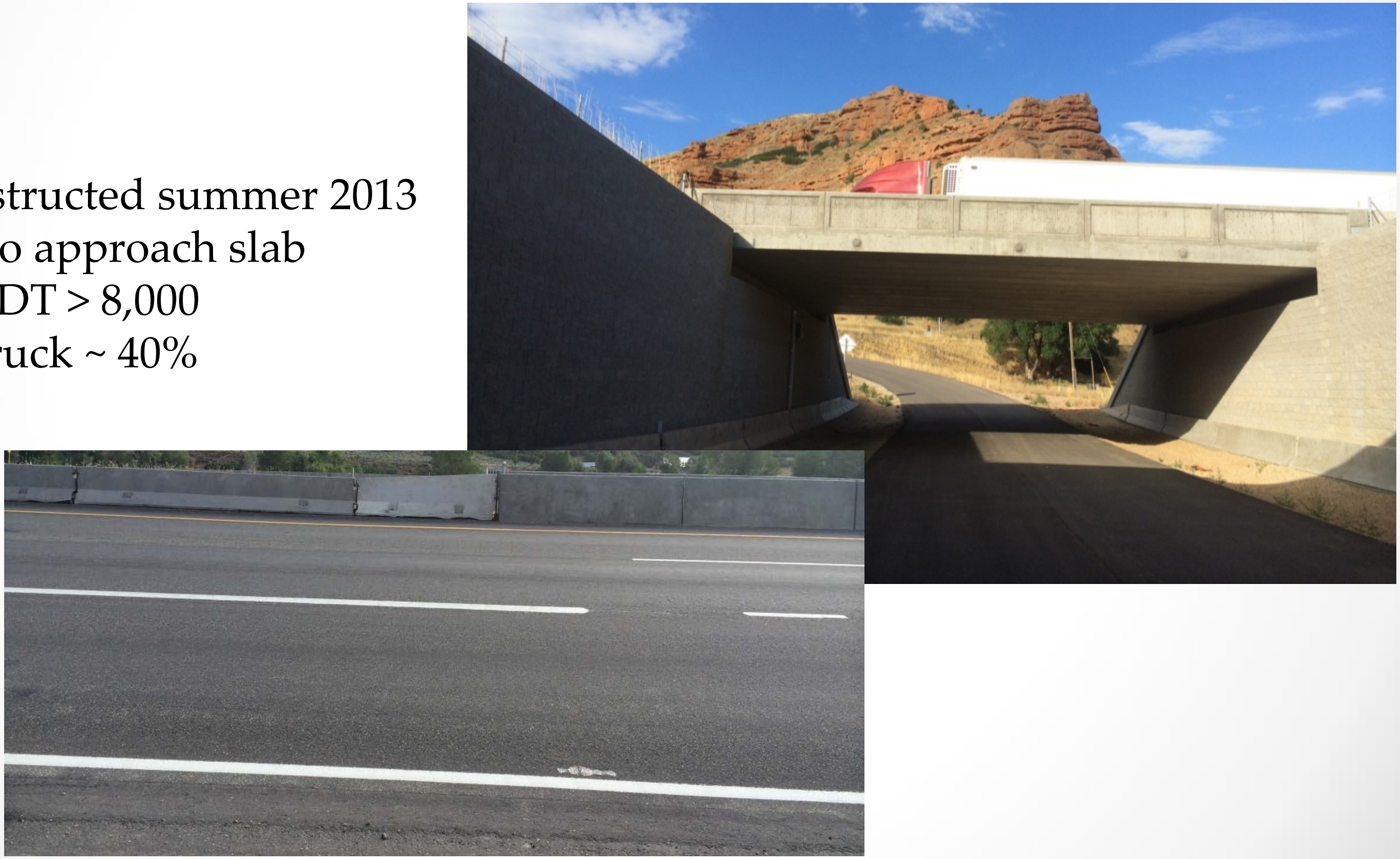


Image source: FHWA

NY – CR47 in St. Lawrence County, NY (2013)

PR – Yauco PR2 (2014)

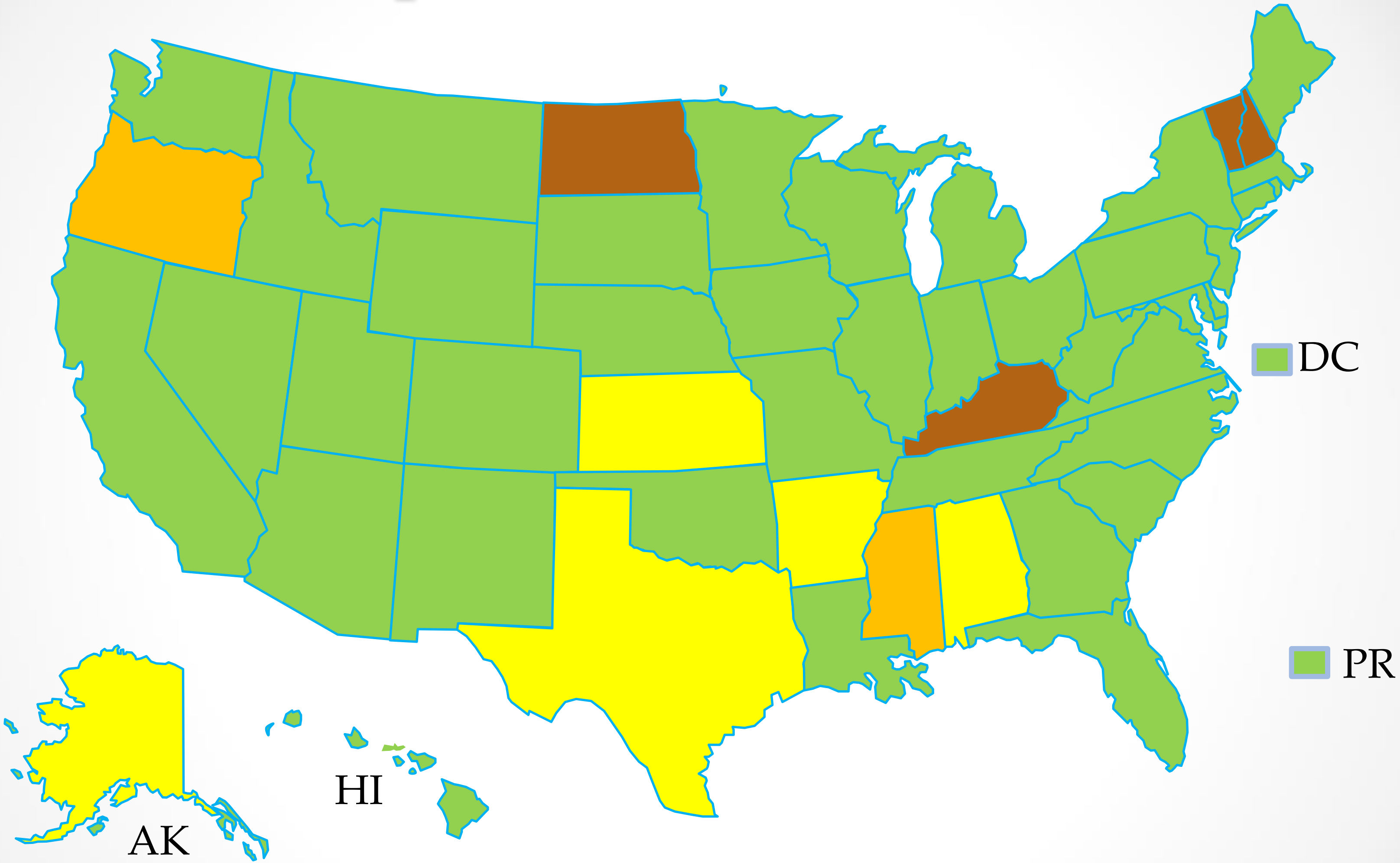
ADT: 40,000

CO – I 70 over Smith Road (2015)

LA – Maree Michael Canal, Vermilion Parish (2015)

MO – Rustic Road Project (2015)

GRS IBS Implementation – October 2016



Legend	Implementation
4	None constructed
2	None constructed but state has been looking for projects on local roads
5	Projects in designed and/or going out to bid
41	Projects Constructed

Questions?