Long-Term Bridge Performance Program: Overview

ENEA

November 2, 2015

Ali Maher, Ph.D.
State of Good Repair in a complex, high-volume, multimodal corridor environment
The Roadway Network

4.1 trillion passenger miles driven per year

± 600,000 highway bridges

3.9 million miles of roadway

U.S. Roadways Transportation Infrastructure System

Carries $8 trillion worth of goods per year (≈60% of U.S. GDP)

4.1 trillion passenger miles driven per year

Steady increase in travel demands 1977–2011
Multimodal SGR

STATE OF GOOD REPAIR

Road Network
- Highways
- Bridges
- Other roads
- Roadside features

Rail Network
- Transit systems
- Freight rail
- Tracks & Ballasts
- Bridges

Ports
- Airports
- Marine Terminals
- Waterways
- Pipelines

Advanced Infrastructure Monitoring
Large-Volume Data & Asset Management
Advanced/Innovative Materials & Devices
Construction Management & Innovation
Education & Workforce Training/Development
- **Reduction of Life Cycle Cost**
  - Advanced condition monitoring systems
  - Data-driven decision support tools
  - Dynamic asset management

- **Improving Resiliency**
  - Mitigate against natural and man made hazards
  - Incorporate climate change effects
  - Safety
CAIT’s National Network of Laboratories

- Utah State University
  Systems Materials and Structural Health Lab
  Utah Transportation Center

- University of Texas at El Paso
  Center for Transportation Infrastructure Systems

- Rutgers, The State University of New Jersey
  Center for Advanced Infrastructure and Transportation

- Virginia Polytechnic Institute
  Virginia Cooperative Center for Bridge Engineering

- University of South Florida
  Center for Urban Transportation Research

- New Jersey Institute of Technology
  Freight Infrastructure Research Lab
  National Center for Transportation and Industrial Productivity

- Columbia University
  Department of Civil Engineering and Engineering Mechanics
  National Center for Aging Infrastructure in Urban Environments

- Princeton University
  Mechanics, Materials, and Structures Laboratory
  Structural Health Monitoring Lab

- University of Delaware
  Center for Innovative Bridge Engineering
  Delaware Center for Transportation Resiliency of Transportation Corridors Center
CAIT’s Key International Partnerships
LTBP Overview

Research Approach & Bridge Selection
Stewardship & Management Challenges

- Aging bridge population
- Funding limitations
- Growing traffic and load demands
- Eliminating deficient bridges
- Performance poorly understood
- Lack of data-driven decision-making tools
The LTBP program will serve as the national platform for strategic long-term investigation of in-service bridge performance...

- To improve bridge health and performance for more effective stewardship and management
- Standardizing and enhancing inspection techniques and criteria
- Enhancing design, construction, preservation and operation practices from data-driven tools
Research Approach

Define Bridge Performance

Determine high priority performance related issues

Design of Experiment
Identify bridges for data collection; Reference cluster concept

Data Analysis Portal Platform

Verify Data Collection Protocols Pilot Program
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ISSUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decks</td>
<td>Untreated Concrete Bridge Decks</td>
</tr>
<tr>
<td>Decks</td>
<td>Bridge Deck Treatments</td>
</tr>
<tr>
<td>Joints</td>
<td>Bridge Deck Joints</td>
</tr>
<tr>
<td>Steel Bridges</td>
<td>Coatings for Steel Superstructure Elements</td>
</tr>
<tr>
<td>Foundations</td>
<td>Reinforced Concrete Substructures Deteriorization</td>
</tr>
<tr>
<td>Concrete Bridges</td>
<td>Reinforced Concrete Superstructure Deteriorization</td>
</tr>
<tr>
<td>New Bridges</td>
<td>Innovative Bridge Designs &amp; Materials (e.g. ABC, FRP)</td>
</tr>
<tr>
<td>Concrete Bridges</td>
<td>Embedded Prestressing Wires and Tendons</td>
</tr>
<tr>
<td>Bearings</td>
<td>Bridge Bearings</td>
</tr>
<tr>
<td>Decks</td>
<td>Precast Concrete Deck Systems</td>
</tr>
<tr>
<td>Joints</td>
<td>Integral Abutments and Jointless Structures</td>
</tr>
</tbody>
</table>
Based on input from stakeholders and considering current resources of the program, the following key topics will initially be addressed:

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ISSUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decks</td>
<td>Untreated Concrete Bridge Decks</td>
</tr>
<tr>
<td>Decks</td>
<td>Treated Concrete Bridge Decks</td>
</tr>
<tr>
<td>Joints</td>
<td>Bridge Deck Joints</td>
</tr>
<tr>
<td>Bearings</td>
<td>Bridge Bearings</td>
</tr>
<tr>
<td>Steel Bridges</td>
<td>Coatings for Steel Superstructure Elements</td>
</tr>
<tr>
<td>Concrete Bridges</td>
<td>Prestressed Wire, Strands, and Tendons</td>
</tr>
</tbody>
</table>
Define Bridge Performance

Determine high priority performance related issues

Design of Experiment
Identify bridges for data collection; Reference cluster concept
Research Approach

1. Define Bridge Performance
2. Determine high priority performance related issues
3. Design of Experiment
   - Identify bridges for data collection; Reference cluster concept
4. Data Analysis Portal Platform
5. Verify Data Collection Protocols Pilot Program
## Selection of Experimental Variables

**Potential Experimental Variables** (Available in either NBI or other comprehensive databases)

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Climate</td>
</tr>
<tr>
<td>Maximum Span Length</td>
<td>ADTT</td>
</tr>
<tr>
<td>Bridge Type</td>
<td>State - Design Practices</td>
</tr>
<tr>
<td>State - Winter</td>
<td>Preventative Maintenance</td>
</tr>
<tr>
<td>State - Preventive</td>
<td>Feature</td>
</tr>
<tr>
<td>State - Maintained</td>
<td>Intersected</td>
</tr>
<tr>
<td>Deck Treatments</td>
<td>Airborne Agents - chlorides, sulides, etc</td>
</tr>
<tr>
<td>Climate</td>
<td>ADTT</td>
</tr>
<tr>
<td>ADTT</td>
<td>State - Winter</td>
</tr>
<tr>
<td>State - Preventive</td>
<td>Feature</td>
</tr>
<tr>
<td>State - Maintained</td>
<td>Intersected</td>
</tr>
<tr>
<td>Deck Treatments</td>
<td>Airborne Agents - chlorides, sulides, etc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance Issues</th>
<th>Attributes</th>
<th>Performance of Untreated Decks</th>
<th>Performance of Treated Decks</th>
<th>Performance of Bearings</th>
<th>Performance of Joints</th>
<th>Performance of Steel Coatings</th>
<th>Performance of PS Conc Girders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential primary influence</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td>Potential secondary influence</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>S</td>
<td>S</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Likely not influential or not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- P: Potential primary influence
- S: Potential secondary influence
- Likely not influential or not applicable
# Design of Experiment

**>> Experimental Variables**

## Untreated Decks

<table>
<thead>
<tr>
<th>Potential Experimental Variables</th>
<th>Age</th>
<th>Live Load</th>
<th>Env.</th>
<th>Str.</th>
<th>Details</th>
<th>Mat'l</th>
<th>Const.</th>
<th>Maint.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What influence do truck loads and truck volumes have on long-term deterioration of bridge decks?</td>
<td>V</td>
<td>V</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>What are the influences of environment (rain/snowfall, deicing, marine environment, temperature range) on rate of deterioration of decks?</td>
<td>V</td>
<td>C</td>
<td>V</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>What influences do structural configuration (girder spacing, span length, continuity, skew) have on structural dynamics and initiation or progression of deck cracking?</td>
<td>V</td>
<td>C</td>
<td>C</td>
<td>V</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>
Identify Bridges for Data Collection: Challenges

- Size and diversity of the population
- Funding – Can not address all performance issues
- Coordination and logistics – mobilization and coordination with state agencies
- Sample size

Combination of these issues has led to the concept of **Reference & Cluster Approach**
13 Recommended Clusters
Recommended Corridors

Corridor Candidates
4890 bridges of all types meeting other selection criteria
Reference Bridge and Supporting Cluster

Comparison: Reference vs. Cluster
Influences of Inputs: Traffic
Influences of Attributes: Materials, Protective Systems, Structural Form/Complexity, etc.
Establish typical levels of variability

Targeted Technology
Cursory NDE
Short-term response monitoring
Ambient vibration

Visual Inspection
Non-standard
Arms length
Segmental
Conventional Tools

Reference bridge
Cluster bridges

Approximate Scale: 30 mi
Reference Bridge

Visual Inspection
- Non-standard
- Arms length
- Segment-based
- Conventional Tools

Global Testing
- Load Testing
- Modal Testing
- Continuous Monitoring

NDE
- Impact Echo
- GPR
- Ultrasonic
- Seismic
- Resistivity

Materials Testing
- Material Sampling
- Stiffness, Strength, Porosity
- Chloride Content

Approximate Scale: 200 ft
Research Approach

Define Bridge Performance

Verify Data Collection Protocols
Pilot Program

Determine high priority performance related issues

Identify bridges for data collection; Reference cluster concept

Data Analysis Portal Platform
Long Term Bridge Performance Program (LTBP) Bridge Portal
Q: What is the LTBP Bridge Portal?

- A centralized, national-level repository for efficiently and quickly accessing and querying bridge performance-related data and information

Combined With

- Data-driven deterioration modeling, GIS mapping, and other data and statistical data analysis tools
Long Term Bridge Performance Program (LTBP) Bridge Portal

Q: What are some of the Benefits LTBP Bridge Portal?

- Combines bridge infrastructure data sources into centralized data repository for analysis, interpretation, and data-driven predictive modeling
- User Friendly, no manual needed
- Visualize the data on the map
- Generates charts/reports quickly
- View/Interpret historical data

- Provides storage of and access to LTBP Program data\research
- Provides a greater understanding of bridge performance

Long-Term Bridge Performance Program
Long Term Bridge Performance Program (LTBP) Bridge Portal
Prestressed Multi-Girder Bridges – Deck Condition of Bridges Shown by Color

Bridge Query Summary Report

GIS Map Visualization Capabilities
(Example: Bridge Deck Condition State)

Charting Capabilities
(Example: Distribution of Bridges by State)
Long Term Bridge Performance Program (LTBP) Bridge Portal
Prestressed Multi-Girder Bridges (I-95 Corridor) – Deck Condition of Bridges Shown by Color

GIS Map Visualization Capabilities
(Example: Bridge Deck Condition State – I-95 Corridor Only)
Long Term Bridge Performance Program (LTBP) Bridge Portal
Prestressed Multi-Girder Bridges (I-95 Corridor) – Query Results Summary Report

**Bridge Query Summary Report**

- **# of Bridges**: 516
- **Cumulative Deck Area**: 1,175,354.00
- **Average Age**: 24.22
- **# of Scour Critical**: 7
- **Average Deck Condition All Bridges**: 6.99
- **Average Deck Condition NHS Bridges**: 6.99
- **# of SD Bridges**: 6 (1.16%)

With a simple click the Portal can provide an overall statistical summary of the query results almost instantaneously.

- # bridges
- # sq ft deck
- Average Age
- ADT/ADTT
- # postings
- # Scour Critical
- Condition States
- Comparisons

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>516</td>
<td>1,175,354.00</td>
<td>2,610,023</td>
<td>24.22</td>
<td>6 (100.00%)</td>
<td>30,704.70</td>
<td>0 (0.00%)</td>
<td>7 (100.00%)</td>
</tr>
<tr>
<td>State</td>
<td>516</td>
<td>1,175,354.00</td>
<td>2,610,023</td>
<td>24.22</td>
<td>6 (100.00%)</td>
<td>30,704.70</td>
<td>0 (0.00%)</td>
<td>7 (100.00%)</td>
</tr>
<tr>
<td>Local</td>
<td>0</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>0.00</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Interstate</td>
<td>504</td>
<td>1,149,300.00</td>
<td>2,583,685</td>
<td>24.03</td>
<td>6 (100.00%)</td>
<td>30,704.70</td>
<td>0 (0.00%)</td>
<td>7 (100.00%)</td>
</tr>
<tr>
<td>NHS</td>
<td>514</td>
<td>1,162,563.00</td>
<td>2,609,690</td>
<td>24.22</td>
<td>6 (100.00%)</td>
<td>30,704.70</td>
<td>0 (0.00%)</td>
<td>7 (100.00%)</td>
</tr>
<tr>
<td>Non NHS</td>
<td>2</td>
<td>12,650.76</td>
<td>333 (0.61%)</td>
<td>24.00</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
</tr>
</tbody>
</table>
Long Term Bridge Performance Program (LTBP) Bridge Portal

Welcome to LTBP Bridge Portal

To learn more about the LTBP Bridge Portal please contact: Dr. Robert Zobel, HRDI-60 LTBP Program Coordinator (202) 493-3024 or robert.zobel@dot.gov
Traditional Deterioration Learning Approach

- Inherently assume that the chosen model specification best describes deterioration. → **Problematic**
- Only very poor fit would motivate new choice of model specifications. → **Compromised Accuracy**
- Only one model specification can be considered every time. → **Inability to Incorporate Different Opinions**

**ISSUE:** Data should determine model specification, not subjective judgments
Traditional Deterioration Learning Approach - Modified

- Data (to drive learning)
  - Determine Deterioration Model Specification
  - Estimate Model Suitability with Data

Subsequent Data Update

Ideally...
LTBP Data-Driven Deterioration Modeling Methodology ($D^3M^2$)

A modified approach to “learning”
Research Approach

1. Define Bridge Performance
2. Determine high priority performance related issues
3. Verify Data Collection Protocols; Pilot Program
4. Identify bridges for data collection; Reference cluster concept
5. Data Analysis Portal Platform
RUTGERS
Center for Advanced Infrastructure and Transportation

RITA Transportation Innovation Series
LTBP Overview

Pilot Program 2008-2011

[Image: RUTGERS logo and UTILITY DEPT of TRANS logo]
Pilot Study Objectives

- Validate Draft Protocols and Procedures for:
  - Data Collection
  - Data Housing and Analysis (Bridge Portal)
  - QA/QC
  - Field Coordination

- Refine & Streamline Testing Methodologies

- Collect Early and Useful Data
Pilot States & Bridge Types

- **New Jersey**: Simple span steel stringer
- **Virginia**: Continuous steel stringer
- **Utah**: Simple span pre-stressed concrete stringer
- **California**: 2-span prestressed post-tensioned continuous CIP box girder
- **Minnesota**: Steel deck truss
- **New York**: Two simple spans of adjacent concrete box beams
- **Florida**: Precast, segmental post-tensioned concrete box beams
Well defined protocols and conventions, supported by quality control tools, are needed to ensure **repeatability and reliability** of data collected

NDE technology is a **valuable tool** for characterization and monitoring of deck deterioration

**Good correlation** between NDE surveys and physical testing

Increasing **speed of NDE data collection** will be essential as the LTBP Program moves into the next phase
LTBP Overview

NDE/NDT Evaluation
• About 600,000 bridges in the U.S. are of an average age of almost 45 years.
• Concrete decks, due to their higher exposure, deteriorate faster than other bridge components.
• Between 50 and 85% of bridge maintenance funds are spent to repair or replace portions of the Nation’s 2.8 billion square feet of bridge decks.
• Conservative estimate is that more than $5B is spent annually to maintain, repair and replace bridge decks.
Reinforced Concrete Deterioration Types of Primary Interest

- Corrosion
- Delamination
- Concrete Degradation
Deck Evaluation - State of Practice
Deck Condition Assessment Vs. NDE Method

Bridge Deck Condition
- Rebar Corrosion
- Delamination
- Spalling

Methods:
- GPR
- Impact Echo
- Chain Drag/Hammer Sounding
- Visual Inspection
- Half-Cell Potential
- Ultrasonic Echo
- IR Thermography
- Electrical Resistivity

Time
Comparison of Electrical Resistivity Results
September 2009 and August 2011

Corrosive Environment from Electrical Resistivity (kOhm-cm)

2009 Testing

2011 Testing
Comparison of GPR Assessments
September 2009 and August 2011

Depth Corrected GPR Condition Maps

Signal Attenuation (Normalized dB) as Condition Indicator

FAIR SERIOUS POOR GOOD

Comparison of GPR Assessments
September 2009 and August 2011

Depth Corrected GPR Condition Maps

Signal Attenuation (Normalized dB) as Condition Indicator

FAIR SERIOUS POOR GOOD

2009 Testing
2011 Testing
Comparison of 2009, 2011 and 2014 Condition Ratings of the Virginia Bridge

Condition rating on a scale 0 (worst) to 100 (best).

<table>
<thead>
<tr>
<th>NDT Condition Assessment</th>
<th>2009</th>
<th>2011</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Corrosion</td>
<td>39.4</td>
<td>28.1</td>
<td>25.8</td>
</tr>
<tr>
<td>Delamination Assessment</td>
<td>70.0</td>
<td>57.2</td>
<td>39.8</td>
</tr>
<tr>
<td>Concrete Degradation</td>
<td>48.1</td>
<td>35.3</td>
<td>26.4</td>
</tr>
<tr>
<td>Combined NDT Rating</td>
<td>52.5</td>
<td>40.2</td>
<td>30.6</td>
</tr>
<tr>
<td>NBI Rating (Visual)</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

**Example:** Delamination rating = (% of sound area X 100 + % of area with initial delamination X 50 + % of area with severe delamination X 0)/100
Approximate Deterioration Curves for Haymarket Bridge

- **Active Corrosion**
- **Delamination**

Condition Rating vs Year graph
Robotic Assisted Bridge Inspection Tool (RABIT)
Joint CAIT&FHWA Development
3D Visualization of Deterioration
Impact Echo Data Superimposed on LiDAR Image
Thank You!

Winner of 2013 ASCE Charles Pankow Award for Innovation & USDOT Secretary Award
Nondestructive Rehabilitation System (NRS)
STATE OF THE ART BRIDGE CAPACITY ESTIMATION

1. Observation and conceptualization
2. A-priori modeling
3. Controlled experimentation
4. Processing and interpretation of data
5. Model calibration and parameter ID
6. Utilization of model for simulations

Structural Identification
Step 1
Rapid modal impact testing using a self-contained mobile device

Step 2
Semi-Automated pre- and post-processing to obtain global frequencies and mode shapes

Step 3
Automated FE modeling using NBI data and on-site assessment

Step 4
Automated FE model calibration and load rating

Step 5
Reporting
Comparison with Best Practices Approach

MIMO Impact Testing

Mode 1: 13.18 Hz
Mode 2: 20.31 Hz
Mode 3: 40.92 Hz
Mode 4: 50.78 Hz

Rapid Impact Testing

Mode 1: 13.51 Hz
Mode 2: 20.47 Hz
Mode 3: 39.46 Hz
Mode 4: 49.65 Hz
### Comparison with Current Structural Testing Approaches

<table>
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</thead>
<tbody>
<tr>
<td>Ambient monitoring w/ displacement transducers</td>
<td>$30-$50K</td>
<td>5-10 days</td>
<td>2-5 day</td>
<td>3-5 days</td>
<td>Yes</td>
<td>Only underside</td>
<td>Mod</td>
</tr>
<tr>
<td>Load testing w/ displacement transducers</td>
<td>$30-$50K</td>
<td>5-10 days</td>
<td>1 day</td>
<td>3-5 days</td>
<td>Yes</td>
<td>Partial 2 hrs</td>
<td>High</td>
</tr>
<tr>
<td>Ambient vibration monitoring</td>
<td>$20-$30K</td>
<td>5-7 days</td>
<td>2-5 days</td>
<td>5-7 days</td>
<td>Yes</td>
<td>Only underside</td>
<td>Mod</td>
</tr>
<tr>
<td>MIMO Impact Testing</td>
<td>$40-$60K</td>
<td>5-7 days</td>
<td>1 day</td>
<td>5-7 days</td>
<td>Yes</td>
<td>Partial 2 hrs</td>
<td>High/Mod</td>
</tr>
<tr>
<td>Rapid Load Testing System</td>
<td>Low</td>
<td>N.A.</td>
<td>1-3 hrs</td>
<td>1-2 hrs</td>
<td>No</td>
<td>Slow downs</td>
<td>Mod</td>
</tr>
</tbody>
</table>
Rapid Evaluation of Bridge Load Capacity (THMPR) – Collaboration with TFHRC, FHWA
Truck fire under bridge
Owner to close a lane to traffic
Resulted in major traffic headache for commuters
Drones in Bridge Condition Monitoring – Collaboration with TFHRC-FHWA
Fiber Optic Bragg Grating Sensors for WIM

CAIT-Rutgers
RUTGERS

Center for Advanced Infrastructure and Transportation

A U.S. Department of Transportation University Transportation Center

Bridge Evaluation and Accelerated Structural Testing Lab

August 12, 2015
BEAST: Mission

For the first time, will allow the scientific study of deterioration processes on full-scale bridge decks in a rapidly compressed time. The lines of innovation:

- Calibrate field data with BEAST data to estimate/forecast remaining service life for much larger population of bridges
- Develop reliable deck deterioration models
- Evaluation of numerous technologies, materials and components
- Validating new technologies being developed to augment bridge deck inspection
<table>
<thead>
<tr>
<th>Specification</th>
<th>Bridge Deck Tester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Specimen Size</td>
<td>50-ft span by up to 28-ft wide</td>
</tr>
<tr>
<td>Specimen Superstructure Depth</td>
<td>Up to 60 inches above floor</td>
</tr>
<tr>
<td>Overall Length (ft)</td>
<td>Approximately 125 feet</td>
</tr>
<tr>
<td>Overall Weight (lb)</td>
<td>120,000 lb</td>
</tr>
<tr>
<td>Max Normal Load (lb) Normal</td>
<td>60,000</td>
</tr>
<tr>
<td>Min Normal Load (lb) Normal</td>
<td>10,000</td>
</tr>
<tr>
<td>Trafficking Speed (mph)</td>
<td>0 to 20</td>
</tr>
<tr>
<td>Primary Drive System</td>
<td>Electric winch</td>
</tr>
<tr>
<td>Drive System Power (hp)</td>
<td>400 HP</td>
</tr>
<tr>
<td>Axle Size</td>
<td>Two Full 30,000 lb capacity each</td>
</tr>
<tr>
<td>Portability</td>
<td>Lateral movement provided between loading cycles</td>
</tr>
<tr>
<td>Bi-directional Loading</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>3 Phase 480 Volt</td>
</tr>
<tr>
<td><strong>Concrete</strong></td>
<td>Any concrete bridge deck mix design, corrosion inhibitors, supplemental cementing materials, and additives</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Decking Systems</strong></td>
<td>Open, filled, partially-filled or unfilled grid decks such as exodermic bridge deck systems; orthotropic or other metal deck systems; prefabricated deck systems; precast slabs; and others</td>
</tr>
<tr>
<td><strong>Rebar</strong></td>
<td>Steel, epoxy coated, galvanized, stainless steel, steel clad, glass and carbon fiber polymer, etc.</td>
</tr>
<tr>
<td><strong>Prestressing &amp; Post-tensioning Strands</strong></td>
<td>Bar, wire, strands, couplers, anchorages, ducts, and other components</td>
</tr>
<tr>
<td><strong>Coatings &amp; Sealants</strong></td>
<td>Latex-modified concrete, joint sealants, epoxy waterproofing seal coating, etc.</td>
</tr>
<tr>
<td><strong>Superstructure Frames</strong></td>
<td>Structural steel, reinforced concrete, precast concrete, prestressed concrete, and timber</td>
</tr>
<tr>
<td><strong>Joints</strong></td>
<td>Preformed joint filler, elastomeric joint assemblies, strip seal expansion dams, modular bridge joint systems, longitudinal joints, shear locks, and others</td>
</tr>
<tr>
<td><strong>Bearings</strong></td>
<td>Bearing pads, reinforced elastomeric bearing assemblies, high-load multi-rotational bearing assemblies, and others</td>
</tr>
<tr>
<td><strong>Deck Drainage</strong></td>
<td>Scuppers, inlets, downspouts, grates, and other drainage elements</td>
</tr>
<tr>
<td><strong>Safety Devices</strong></td>
<td>Stripping paint, pavement reflectors, auditory safety devices (e.g., Bott's dots, rumble strips, etc.), ITS devices and sensors, traffic cams, signage materials, and more</td>
</tr>
</tbody>
</table>
BEAST: Superstructure Plan and Select Details

Flexible Specimen Envelope:
- Up to a 5-ft superstructure depth
- Multiple girder options
  - Steel, concrete
  - Spacing
  - Shapes (I, Box, Tees)
  - Various framing details
- Deck joint systems
- Bearing assemblies
Site Location – Livingston Campus

Access to major routes:
- Route I-95 – 6.5 miles
- Route I-287 – 5.5 miles
- NJ Route 18 – 2 miles
- NJ Route 1 – 5 miles
The BEAST in Action!
BEAST: Rolling @ 20 mph >>
International Bridge Study (IBS)

International collaborative study of a bridge in New Jersey to demonstrate and document best practices and technology selection for bridge health assessment and monitoring.
Industry, government, and academic teams from Austria, Canada, China, Great Britain, Japan, Korea, Switzerland, and the United States participated.
Contribute curriculum and fieldwork to educate current and future DOT/FHWA workforce, bridge inspectors, practicing engineers, and technology providers.

Test bed for validation of new/emerging technologies.

Create field calibration QA/QC “hubs” for inspectors and technology providers.

Advance technology applications to diagnosis and prognosis of bridge-specific concerns.

Leverage technology more effectively by establishing proper integration and application standards for common bridge types and performance issues.
China
• Southeast University

European Union
• Sheffield University (United Kingdom)
• Vienna Consulting Engineers (Austria)
• École Polytechnique Fédérale de Lausanne (Switzerland)

Japan
• University of Tokyo
• Central Nippon Expressway Co. (NEXCO-W)
• Keisoku Research Consultant

South Korea
• KAIST
• Seoul National University
• INHA University
• Pyunghwa Engineering Consultants
• Korea Expressway Corporation
• SEJONG University

United States
• Rutgers CAIT
• Intelligent Infrastructure Solutions
• Drexel University
• Princeton University
• Utah State University
• University of New Hampshire
• Western Michigan University
• Georgia Tech
• Inspecttech
• Parsons Brinckerhoff
• Pennoni Associates
• Olsen Engineering
• Smart Structures
Thank You!

Questions?  >>

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Thank you!