CAIT-UTC-NC11

Development of Protocols and Instrumentation Plan for Accelerated Structural Testing Facility

FINAL REPORT
June 2017

Submitted by:

Franklin L. Moon
Professor

Ali Maher, Professor and CAIT Center
Professor and CAIT Center Director

Nenad Gucunski
Professor

Hao Wang
Associate Professor

Jie Gong
Associate Professor

Andres Roda
Research Manager

Center for Advanced Infrastructure and Transportation (CAIT)
Rutgers, the State University of New Jersey
100 Brett Road
Piscataway, NJ 08854

External Project Manager
Nat Kasbekar
New Jersey Department of Transportation
1035 Parkway Avenue
Trenton, NJ 08625

In cooperation with

Rutgers, The State University of New Jersey
And
State of New Jersey
Department of Transportation
And
U.S. Department of Transportation
Federal Highway Administration

Disclaimer Statement

The Center for Advanced Infrastructure and Transportation (CAIT) is a National UTC Consortium led by Rutgers, The State University. Members of the consortium are the University of Delaware, Utah State University, Columbia University, New Jersey Institute of Technology, Princeton University, University of Texas at El Paso, Virginia Polytechnic Institute, and University of South Florida. The Center is funded by the U.S. Department of Transportation.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CAIT-UTC-NC11		
4. Title and Subtitle **Development of Protocols and Instrumentation Plan for Accelerated Structural Testing Facility**		5. Report Date June 2017 6. Performing Organization Code CAIT/Rutgers University
7. Author(s) Franklin Moon, Ali Maher, Nenad Gucunski, Hao Wang, Jie Gong and Andres Roda		8. Performing Organization Report No. CAIT-UTC-NC11
9. Performing Organization Name and Address Center for Advanced Infrastructure and Transportation Rutgers, The State University of New Jersey 100 Brett Road Piscataway, NJ 08854		10. Work Unit No. 11. Contract or Grant No. DTRT13-G-UTC28
12. Sponsoring Agency Name and Address Center for Advanced Infrastructure and Transportation Rutgers, The State University of New Jersey 100 Brett Road Piscataway, NJ 08854		13. Type of Report and Period Covered Final Report 8/1/14-6/30/15 14. Sponsoring Agency Code
15. Supplementary Notes U.S. Department of Transportation/OST-R 1200 New Jersey Avenue, SE Washington, DC 20590-0001		
16. Abstract Long-term bridge performance is currently not well understood. In practice, engineers are forced to rely heavily on expert opinion, anecdotal experiences, and generalizations. This research project served as step 1 in the master plan to retrieve critical, quantitative bridge deterioration data. The infusion of NDE, temperature, strain, and other critical data borne out of this program serves to inform, in a rapid manner, bridge managers and modelers in the development of increasingly accurate deterioration algorithms. Corrections made to refine the models and funding charts relied-upon by decision-makers to maintain their bridge inventory.		
17. Key Words Accelerated structural testing, state of good repair, superstructure analysis, deterioration modeling, bridge management, structural analysis, finite element method, corrosion, reinforcement, rebar, concrete, bridge deck, nondestructive evaluation		18. Distribution Statement
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages Total #21 22. Price

Form DOT F 1700.7 (8-69)

Table of Contents

Contents

List of Figures

List of Tables

Introduction

Long-term bridge performance is currently not well understood. In practice, engineers are forced to rely heavily on expert opinion, anecdotal experiences, and generalizations. Although these approaches have served the profession well, with the move towards more advanced asset management strategies to reduce life-cycle costs, they are no long sufficient. Rather, modern, quantitative management systems demand more reliable performance models and more accurate and objective estimates of the effectiveness of various interventions.

To date, bridge deterioration is almost exclusively studied using either (a) direct observations of the performance of operating bridges (using visual inspection, NDE, sensing, etc.), or (b) standardized durability tests that operate on small-scale material specimens. Unfortunately, neither of these approaches can generate the type of objective, quantitative and reliable information on long-term bridge performance needed to implement modern asset management systems.

In the case of field observations, the glacial time-scales over which deterioration occurs means that it can only be observed from bridges in service for 15 to 20 years (or even longer). This greatly hampers its ability to inform decisions about the long-term performance of more current bridge systems (which employ different materials, details, construction practices, etc.) or to inform decisions about emerging details/components and materials for new design. That is, by the time the information about performance becomes available, the practice has changed and thus the relevance of the performance information to this new practice is questionable.

On the other hand, in the case of material-level tests, although they can be carried out in a relatively rapid manner (over the course of several months) they fail to address the multiple and compounding inputs that bridges experience in operation (inclusive of live load, environmental, winter maintenance, etc.). The results may be applicable to individual deterioration mechanisms e.g. freeze-thaw) but cannot begin to simulate how the various deterioration mechanisms interact to produce the long-term performance observed in practice. In addition, due to the reduced scale of these specimens, there are many open questions about the extent to which these tests simulate the actual deterioration mechanisms as they occur within a complete bridge system.

Specifically, this research will utilize the recently commissioned Bridge Evaluation and Accelerated Structural Testing (BEAST) Lab at Rutgers University (Figure 1). This unique facility is capable of applying realistic demands to a full-scale bridge superstructure in an accelerated manner, which include:

(a) Live load applied through rolling wheel loads to simulate the wear-and-tear on deck surfaces (as opposed to stationary actuators). The load configuration is equivalent to the rear carriage of a tractor trailer and can impose forces from 10 kip up to 60 kip to simulate live load demands on primary components (e.g. deck, girders).

(b) Temperature fluctuations applied to simulate both freeze-thaw and hot-dry cycles to the bridge specimen. The tests are expected to impose at least 280 freeze-thaw cycles (0F to 50F) and at least 120 hot-dry cycles (50F to 100F) during the 9-month duration of the experiment.

(c) Application of de-icing agents to the bridge specimen to simulate common winter maintenance practices. A brine solution with up to 18% NaCl can be deployed during any phase of the accelerated testing.

A description of the BEAST Lab is provided in Appendix A. Additional information, including a mini-documentary on the laboratory can be found at cait.rutgers.edu/beast.

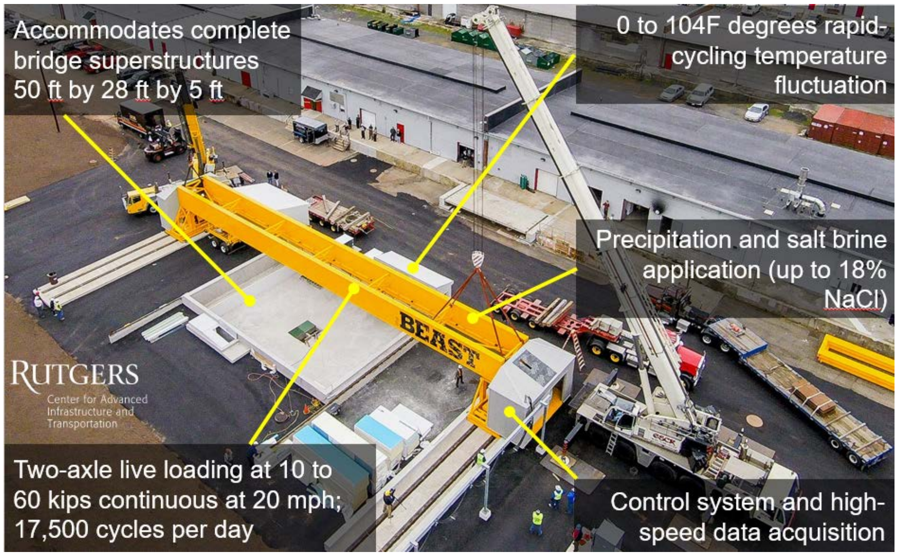

Figure 1– Bridge Evaluation and Accelerated Structural Testing (BEAST) Laboratory

Proposed Four-Phase Research Study

The proposed research is separated into four phases that will focus on different aspects of long-term bridge performance. The following subsections provide a summary of the anticipated primary focus of each phase. More detailed objectives and scope for Phase I have been developed and are presented in the following section. In contrast, Phases 2, 3, and 4 are still under preliminary development at this stage, as the results of completed phases are expected to have a significant influence over the details of any subsequent phase.

Phase 1 Summary

This initial phase will focus on the long-term performance of contemporary untreated reinforced concrete bridge decks (HPC, various rebar coatings, etc.). The test specimen will be composed of a common steel multi-girder superstructure with a composite deck to allow the long-term performance of various steel coatings, joints, and bearings to be quantified. Of particular interest during this phase will be the development of quantitative deterioration curves as well as the validation/refinement of the durability-related "deemed-to-satisfy" provisions provided by both domestic (e.g. AASHTO and state specifications) and international standards. In later sections (and in Appendices B through F) additional details are provided relating to the activities proposed for Phase I.

Phase 2 Summary

The primary focus on Phase 2 will be on the long-term performance of common bridge deck repair, preservation or overlay systems. Using the specimen aged under Phase 1, this phase will provide a quantitative comparison of multiple interventions intended to extend the service life of bridge decks. The specific intervention strategies examined will be based on discussions with the project panel following the completion of Phase 1. In addition, it is expected that this phase will also permit the on-going assessment of the long-term performance of the various steel coatings examined under Phase 1, and perhaps the effectiveness of local repair strategies to extend their service life. Although it is difficult to estimate the budget for Phase 2 due to the uncertainty associated with the scope, there will be a cost savings since the specimen from Phase 1 will largely be reused (with only the addition of the deck repair/overlay interventions required).

Phase 3 Summary

Two potential alternatives have been identified for the focus of Phase 3. The first would aim to quantify the long-term performance of older, Class A bridge decks with uncoated reinforcement. Although such decks are no longer constructed, they represent a significant percentage of the bridges in service and so their long-term performance is quite relevant to current practice. If the project panel elects for this alternative, it may be possible to reuse Specimen 1 with a full deck replacement.

The second potential focus may be on the long-term performance of more modern bridge decks such as UHPC or systems that are employed in accelerated bridge constriction (e.g., FRP, partials or full-depth precast panels, deck-beam elements, etc.). If the panel selects this alternative (especially if the focus is on various ABC systems/elements) a completely new specimen will likely be required.

Phase 4 Summary

The focus of Phase 4 will depend directly on the direction the project panel decided to take on Phase 3. Regardless of the direction however, it is anticipated that Phase 4 will focus on the effectiveness of various repair and/or preservation activities on long-term performance (of either Class A bridge decks or the more modern UHPC or ABC systems). As a result, a completely new specimen is not expected to be required for Phase 4.

Project Execution

As mentioned above, the specific objectives and scope of Phases 2, 3, and 4 will depend greatly on the results from previous phases. As a result, following the completion of each phase, it is proposed to have a one-day meeting with the project panel to discuss the results and to set the objectives and scope for the next phase of the project.

Depending on the direction set for each phase, changes in both the research team and the project panel may occur. For example, the research team may elect to bring in individuals with expertise specific to the direction of subsequent phases. In addition, some members of the project panel may decide not to participate in all of the phases as they may not be relevant to their state's practice.

Appendix A – Description of the BEAST Laboratory

The Bridge Evaluation and Accelerated Structural Testing (BEAST) Laboratory is a one-of-a-kind testing facility capable of expediting the aging of full-scale bridge superstructures through controlled application of a realistic suite of demands (Figure 1). The ability to both control inputs and accelerate their influences on full-scale bridge systems is a potential game-changer for long-term bridge performance research. More specifically, these unique capabilities will allow researchers, for the first time, to:

(1) Observe the full life cycle of bridge performance (deterioration, initiation, and propagation) in a highly condensed time, and quantify the performance through high-resolution (both spatial and temporal) data collection efforts
(2) Quantitatively decouple the influence of different demands on various deterioration of bridges through controlling the levels of live load, environmental, and maintenance exposure

To accomplish these goals, the BEAST is capable of applying realistic traffic, environmental, and winter maintenance demands in a greatly compressed time frame - simulating approximately 20 years of deterioration within a nine-month time period.

The laboratory itself encloses a 125-foot-long by 75-foot-wide footprint and stands 13 feet above grade. The equipment consists of a load carriage capable of applying 30-kip axle rolling loads to the test specimen as well as 50 ft. by 28 ft. environmental chamber. This chamber is capable of "weathering" the test specimen by simulating seasonal temperature fluctuations (0°F to 104°F) and applying deicing chemicals. The physical and environmental loading on the test samples will simulate actual stress levels exerted by truck traffic on bridge decks and superstructure elements at a greatly accelerated pace.

The live load system of the BEAST is built upon a steel structure consisting of two (winch and sheave) end frames and a pair of box beams. A rail system is suspended under the beams, allowing the load carriage to travel to and from acceleration/deceleration ramps. The carriage is propelled by a 400-hp motor and a winch/sheave pulley system that is capable of achieving a 20-mph constant velocity along the 50-foot specimen envelope. The live load system sits on a pair of synchronized rail carts, allowing for lateral motion along parallel concrete-mounted 80-pound rails. This allows for lateral placement of load lines throughout the width of the specimen, as well as fully opening the environmental chamber for placement and removal of specimens.

The environmental chamber encloses the test specimen under an insulated shell. It also includes all the components for environmental loading: evaporators, condensers, 480V and 240V panels, 480/240V transformer, heaters, and a brine system. The upper portion of the environmental chamber comprises three distinct elements: the end frame environmental enclosures, the beam-mounted insulation, and the foam-paneled roof trusses. The components form the movable portion of the environmental chamber. The end frame enclosures surround the loading ramps, and provide space for the carriage to move off the bridge sample and still be enclosed in the chamber. The beam-mounted insulation provides the environmental enclosure between the load ramps and the roof trusses. The roof truss portion of the environmental chamber is designed to allow the BEAST to be located at different load lines across the test specimen while keeping the chamber environmentally contained. Each roof truss section can be separated from the others and then be relocated to the other side of the BEAST. The lateral adjustment is provided by the beam-mounted insulation that reaches out to cover and interface with the roof trusses. The roof trusses move on the rails that are attached to the abutments. The roof trusses have two wheels on each side that move along these rails, and their seam can be sealed using built-in cam locks.

Specimens will either be delivered by truck (precast slabs) or fabricated on-site (cast-in-place). Specimen delivery/fabrication is anticipated to occur no more than two times during the proposed five-year effort (with specimens being reused for multiple phases), and will require truck and crane for precast, or concrete truck for cast-in-place. This is a common type of practice in construction with little to no impact on the area. Placing specimens in the environmental chamber can be accomplished by rolling the roof modules and the BEAST into the open position. Once specimens are placed inside the environmental chamber, the tester is sealed and locked.

Appendix B – Summary of Service Life Design Approaches

As put forth in ISO 16240 (2012) and fib bulletin 34 (2006), there are two generally accepted strategies to explicitly incorporate durability limit states within design. The first (termed Strategy 1) aims to provide a means for the structure to withstand environmental and repeated load effects without reaching objectionable limit states during the target service life. In practice, this strategy is carried out through one or a combination of the following:

1) By selecting/specifying materials that have sufficient durability to withstand deterioration throughout the design service life
2) By providing protective systems (e.g. reinforcement coating, membranes, overlays, steel coatings, joints, and scuppers)
3) By providing dimensions and details to reduce the rate of deterioration (e.g. cover dimension, reinforcement size, and reinforcement spacing)
4) By selecting a shorter service life for specific elements and planning for their replacement such that their deterioration does not govern the service life of the overall bridge (e.g. joints, bearings, scuppers, and traffic barriers)

The second strategy (Strategy 2) aims to remove the vulnerability of a structure to deterioration through the removal of vulnerable details (e.g. joints) or the use of non-corrosive materials (e.g. stainless steel).

Figure B.1 below (reproduced from ISO 16204) provides the general procedure for Service Life Design. Within this figure, "full probabilistic," "partial factor," and "deemed-to-satisfy," approaches all fall under Strategy 1, while "avoidance of deterioration" falls under Strategy 2.

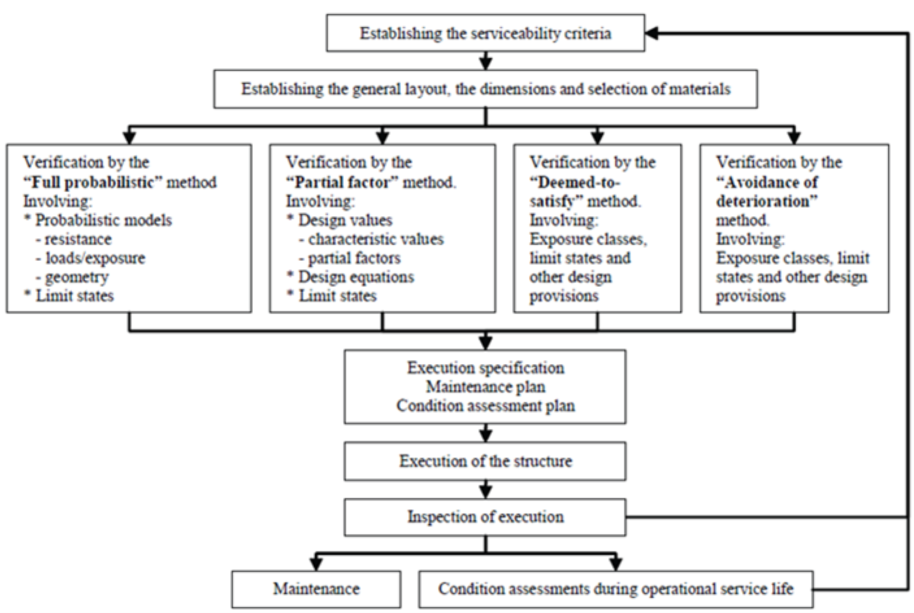

Figure B.1 – Flowchart for service life design (ISO 16240, 2012)

Brief summaries of each of the approaches that fall under Strategy 1 are provided below.

a) *Full probabilistic* – Using this approach, the reliability index for each specific limit state is explicitly computed during the design process using deterioration models.
b) *Partial factor* – Using this approach, partial safety factors (e.g. load and resistance factors) are used to allow designers to evaluate limit states given specific target reliability indices during the design process. The partial factors are computed using the full probabilistic approach. This approach is similar to what is currently implemented in AASHTO LRFD for structural design.
c) *Deemed to Satisfy* – This approach provides designers with a set of prescriptive requirements which, if followed, should produce a bridge with a service life above the minimum specified (for assumed reliability indices). These prescriptive requirements can be developed and or validated using the full probabilistic approach.

Recently, the PI, as part of NCHRP Project 12-108 (Guide Spec for Service Life Design), performed a literature review and synthesis for each of these strategies. Phase 1 of this project will build upon this work and identify opportunities to validate and/or refine the currently available provisions or methodologies through the proposed accelerated testing.

Appendix C – Bridge Specimen Configuration

Given its widespread use in practice, a steel multi-girder with a composite reinforced concrete deck is proposed as the initial specimen. To maximize the usable space within the BEAST Lab, the specimen will have a 27 ft. width and a 50 ft. length. These dimensions will allow for four girders spaced 7 ft. on center with ~3 ft. overhangs along each edge. A span-to-depth ratio of L/25 is proposed for the girders, which gives a girder depth of 2 ft. To permit multiple lines of diaphragms, a spacing of ~16 ft. (which provides two internal diaphragms in addition to those over the supports) is proposed. Given the relatively small girder depth, channel type diaphragms are likely the most realistic option; however, the use of cross frames (perhaps in a chevron configuration) may be considered based on input from the project panel.

To ensure a realistic design, the girders will be sized as per the AASHTO LRFD Bridge Design Specifications based on the simplified single-line girder modeling approach and will be designed to be composite (using standard shear stud connectors and spacing) with the RC deck. This approach is the most commonly used in practice and will result in the most realistic girder and superstructure stiffness and strength characteristics. To permit the examination of various steel coating systems, it is proposed to have each girder employ different coating systems (two different metalizing systems, galvanized, and a common paint system). To permit the evaluation of the coating systems (Objective 2b) and potential corrosion traps, the specimen will be constructed with a longitudinal slope of 2 in. over the 50 ft. length together with an open joint (see Figure C.1).

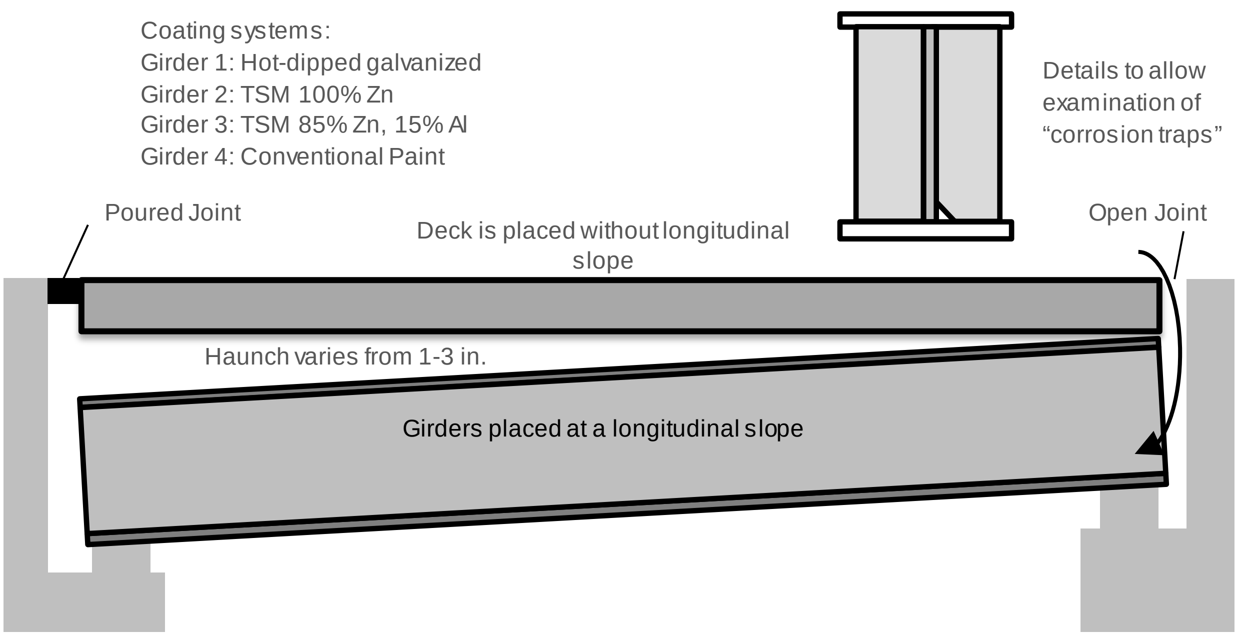

Figure C.1 – Proposed coating and details to permit their long-term performance to be assessed(preliminary and subject to review/approval by the project panel)

The reinforced concrete deck will be constructed using high performance concrete (HPC) and will be 8 in. thick with a specified top cover of 2.5 in. For the purpose of this document, and subject to review and approval by the project panel, the following preliminary suggestions are considered:

- It is envisioned that the HPC specifications developed by the New Jersey Department of Transportation (NJDOT) will be used as it utilizes locally-sourced material.
- To allow for the influence of reinforcement coating to be assessed (Objective 2a), the specimen will be constructed using two difference types of deck reinforcement (as shown in Figure C.2). At this stage it is envisioned that one may employ epoxy-coated reinforcement with the other employing galvanized reinforcement.
- The specimen will be supported by common elastomeric bearings sized as per common practice and incorporate a typical compression and/or poured seal bridge joint.

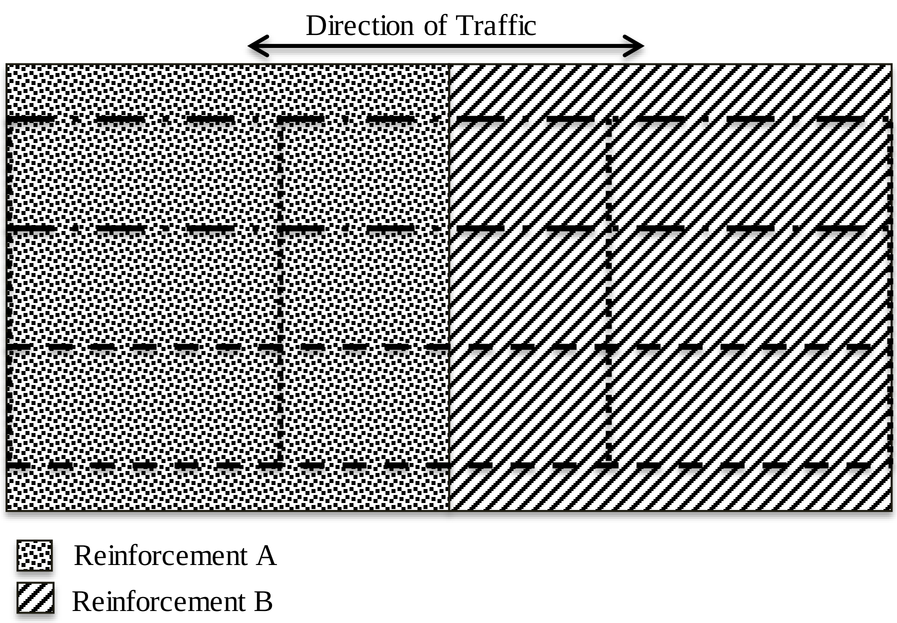

Figure C.2 –Plan view of proposed specimen illustrating the location of different reinforcement type and steel coating (preliminary and subject to review/approval by the project panel)

Appendix D – Proposed Loading Protocols

The following sections provide details associated with the proposed live load, environmental, and winter maintenance loading protocols.

Proposed Live Loading Protocol

The proposed live loading protocol is designed to allow the effects of truck weights on the localized deterioration of the deck to be investigated (Objective 2c). To accomplish this, four tracks are proposed for the live loading (Figure D.1). Tracks 1 and 4 correspond to locating the wheel line of the live load carriage along the centerline between Girders 1 & 2 and Girders 3 & 4, respectively (Figure D.1). These tracks correspond to the least significant demands on the deck as the wheel lines are located very close to the girder lines. In contrast, Track 2 and 3 correspond to locating the center of the live load carriage over Girders 2 and 3, respectively. These tracks maximize the live load effects on the deck and the wheel lines are located in between the girders.

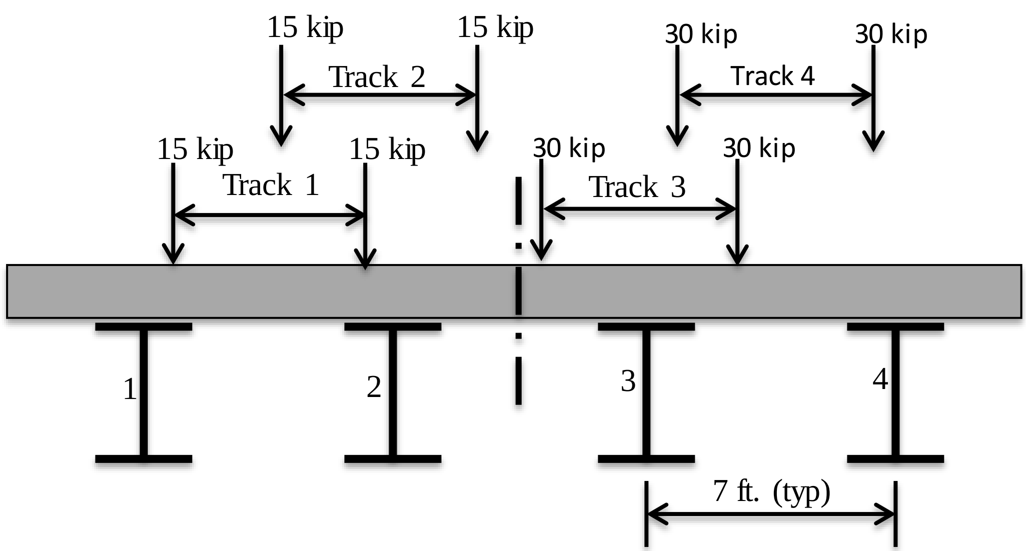

Figure D.1 - Elevation view illustrating the proposed live load location and magnitude (preliminary and subject to review/approval by the project panel)

In addition to varying the spatial location of the live load to simulate realistic force effects, the live load protocol will also vary the magnitude to allow influence of truck weight to be assessed. As illustrated by Figure D.1, the portion of the bridge over Girders 1 & 2 will be exposed to 30 kips of rolling live load (applied using the rear carriage (two axles, eight tires) of a tractor trailer) while the portion of the bridge over Girders 3 & 4 will be exposed to 60 kips of rolling live load. To put these loads into context, the design truck included as part of the HL-93 Live Load has a rear carriage which corresponds to 32 kip.

From a global perspective, this approach does not isolate the effects of truck weight as Girders 1 & 2 will certainly participate in resisting the live load demands associated with Tracks 3 and 4. However, from a more local perspective, i.e. the performance and durability of the deck, this approach does provide significant isolation and was selected to allow Objective 2c to be satisfied.

During the testing it is proposed to constantly expose the specimen to live load in a manner that provides an equal number of cycles to each of the four tracks. It is anticipated that moving the live load transversely to a new track will require approximately 30 minutes, and it is proposed to carry out this relocation every other day. At its maximum capacity, the BEAST is capable of inducing 17,500 cycles of live load per day, which corresponds to an Average Daily Truck Traffic (ADTT) of approximately 900 if an acceleration ratio of 20 is assumed.

Proposed Environmental Loading Protocol

The proposed environmental loading protocol is provided in Figure D.2. As illustrated below the proposed protocol provides seven freeze-thaw cycles and three hot-dry cycles during every week of testing (with 8.5 hours of dwell time following each temperature change). Over the anticipated nine month testing period, this translates into approximately 280 freeze-thaw cycles (note that ASTM C 666 *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing* uses a maximum of 300 freeze-thaw cycles).

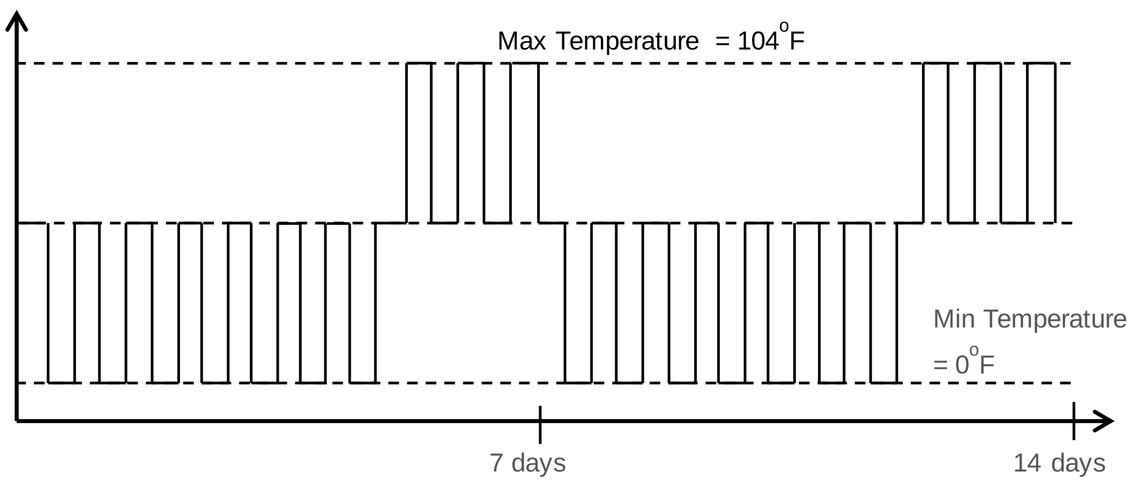

Figure D.2 – Proposed environmental loading protocol (preliminary and subject to review/approval by the project panel)

Proposed Winter Maintenance Loading Protocol

In order to introduce chlorides into the bridge specimen to simulate the effects of winter maintenance practices, during the Freeze Exposure Cycles, a 10% brine solution will be constantly sprayed onto the deck of the specimen by the live load carriage. Since the location of the live load track defines the application region for the brine solution, the solution will be applied so that each track receives equal brine solution during each exposure cycle. Note that the system has the capability of deploying a 18% brine solution, but the 10% solution was selected as it is more realistic.

Appendix E – Proposed Instrumentation and Data Collection

Instrumentation Design and Installation

Once the test bridge design is completed a series of simulation models will be developed and used to finalize the instrumentation program. The goal will be to capture critical responses with high temporal resolution to better understand how deterioration initiates and propagates, and how it influences the manner in which a bridge carries load (inclusive of dead, live, and temperature).

The final instrumentation system will be installed during construction to ensure the capture of dead load effects and the behavior of the test bridge during the curing process. As outlined in Table 1, these sensors will consist of both fiber optic and vibrating wire sensors embedded into the concrete deck and welded to the steel girders. Upon installation the sensors will be connected to an appropriate data acquisition system and data collection will commence.

Data Collection

To satisfy the primary and secondary objectives of the proposed study, a large and diverse array of data collection approaches must be brought to bear. The details of each data collection approach will be finalized during the initial stages of the project through a series of simulation, but all cases data collection efforts will meet or exceed the requirements of the associated LTBP Data Collection Protocols. Table E.1 and E.2 provide a summary of the continuous and periodic data collection approaches, respectively, which are envisioned for the specimen and were assumed for budgeting purposes.

Table E.1 – Preliminary instrumentation for continuous (SHM) data collection

Sensor Type	Location	Response Quantities	Channels
Continuous fiber optic	Embedded in a cross-section of the deck	High spatial resolution of temperature (during and after curing), strain (shrinkage, live load, temperature), humidity	2
Vibrating wire embeddable strain	Embedded in a cross-section of the deck	High resolution point measurements of temperature (during and after curing), strain (shrinkage, live load, temperature)	12
Vibrating wire strain	Sensor groups located at ¼, mid, and ¾ span	Strains (dead load, live load, temperature, curing), degree of composite action (i.e. location of N.A.), distribution factors	36
Vibrating wire displacement	Girder ends to abutment wall	Bearing movement associated with temperature expansion/contraction	2
String potentiometers	Located at ¼, mid, and ¾ span	Vertical displacements, girder stiffness, distribution factors	12
Video	Top, underside, carriage-mounted and “Elevation View”	Images of test operations, rapid-frame capture for deflection measurements	3

Table E.2 – Preliminary estimate of periodic data collection activities

Data Collection Approach	Spatial Resolution	Response Quantities	Estimated # of Data Collection Efforts
Ultrasonic Surface Waves	2 ft by 2 ft	Elastic modulus profile	15
GPR	Continuous	Concrete deterioration and rebar cover	15
Impact Echo	2 ft. by 2 ft.	Presence and depth of delaminations	15
Electrical Resistivity	2 ft. by 2 ft.	Moisture and crack detection	15
Modal Impact Testing	12.5 ft by 7 ft.	Modal frequencies, mode shapes, damping coefficients	15
Visual Inspection	Based on NBIS	Condition ratings to permit comparison with NBI data	4
LiDAR and Thermography	Entire bridge	Presence of delaminations, monitoring structural steel deterioration, slippage between bridge deck and beams and concrete degradation over time	15

Continuous Data Collection (SHM)

Continuous data collection efforts (Table E.1) will occur throughout the test duration and will be monitored on a daily basis for changes in response or behavior. Once the initial response signatures of the test bridge are captured, a series of thresholds will be defined for each sensor (or sensor group) to control the sending of alerts to the research team. It is anticipated that these alerts will range from sensor/data acquisition malfunction (so-called hardware watchdogs) to thresholds that may indicate a change in behavior (or deterioration initiation) that may trigger a periodic data collection effort.

Periodic Data Collection

Periodic data collection (Table E.2) will be carried out based on either time durations or changes in response captured by the continuous monitoring system. It is anticipated that initially the quantitative data collection efforts may be carried out on a bi-weekly basis to ensure the capture the initiation of deterioration. As the response of the test bridge and the propagation of deterioration become clear, it is anticipated that the intervals of data collection will be modified accordingly.

Although the use of the Robotic Assisted Bridge Inspection Tool (RABIT) is envisioned, the majority of the NDE data collection will be carried out manually. This is proposed to ensure that the specific spots from which discrete NDE data (e.g. impact echo) is collected are kept consistent.

Data storage and back-up

The team will develop provisions for off-site data storage and back-up, including data, metadata and images. The team will coordinate with CAIT staff to perform data transfer into Bridge Portal.

Appendix F – Specimen Construction, Test Execution, and Data Interpretation

Specimen Construction

Following the bid procedures required by Rutgers, the research team will select a contractor to construct the steel multi-girder bridge specimen. Throughout the construction process Pennoni Associates Inc. will provide construction inspection and testing services to ensure that all relevant specifications and requirements are met by the contractor. For this initial specimen it is envisioned that construction will take place within the BEAST Lab to reduce the cost associated with transportation and installation.

Test Execution

Following the construction and curing of the specimen the live load, environmental, and winter maintenance loading protocols will commence. As describe above, these loading protocols will be carried out repeatedly each week inclusive of 7 freeze-thaw cycles and 3 hot-dry cycles. Given the 20 fold acceleration of deterioration anticipated, a nine month test duration (22.5 years of aging) was assumed. It is envisioned that down time required for periodic data collection, relocation of live load, and maintenance activities will be minimal and will average less than 12 hours per week.

Data Archival and Interpretation

Throughout the test execution all raw data collected will be stored in multiple redundant locations and will be integrated within the LTBP Bridge Portal. The data will be processed, visualized, and reduced to allow for correlations (temporal and/or spatial) between external inputs (live load, environmental, maintenance), structural behaviors (displacements, strains, etc.), and material deterioration (cracking, delamination, spalling, etc.) to be identified. The research team will apply this process, together with the use of simulation models where appropriate, to satisfy both the primary and secondary objectives proposed above.