CAIT-UTC-006

Bridge Resource Program

Final Report

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Submitted by

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16. Abstract
The mission of Rutgers University's Center for Advanced Infrastructure and Transportation (CAIT) Bridge Resource Program (BRP) is to provide bridge engineering support to the New Jersey Department of Transportation (NJDOT)'s Bridge Engineering and Infrastructure Management Unit. The program is a partnership between federal and state transportation agencies and Rutgers University, which provides technical and educational services to address infrastructure needs in New Jersey. CAIT supports the NJDOT by providing staff and resources to address the most pressing bridge engineering and training challenges in New Jersey (through advanced materials development, design enhancements, construction improvements, evaluation, monitoring, data mining, management enhancement and support, and bridge research).

The overarching goal of the Bridge Resource Program is to achieve more effective asset management. This includes consideration and potential adoption of next generation assessment approaches to augment current reliance on qualitative condition metrics with more quantitative performance metrics. Although conventional engineering terms are used in this proposal to describe program services, the proposed tasks within each service will be focused on providing decision making assistance for concept development.

BRP has provided opportunities to bring technologies to NJDOT, review existing practices, and propose the use of new construction techniques to improve asset management, design and construction practices. In addition, it has created a new channel of communication between CAIT and NJDOT that allows for the rapid deployment of innovative technologies. In the future, the BRP is envisioned to continue to identify opportunities for innovation. It is anticipated that new research topics will be borne out of the program. As research is completed, it can return back to the BRP for pilot testing and recommendation for deployment. The cycle of innovation, testing, implementation and need for further innovation can be perpetuated through the creation of similar resource programs.

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1. Description Of The Problem

New Jersey Department of Transportation (NJDOT) is faced with significant challenges in addressing the state of good repair of their bridge asset system. Shrinking budgets and the need to "do more with less", has resulted in increasingly difficult decisions to repair or replace structurally deficient bridges. The state's current investing budget, $690 million in 2013 on bridge assets, follows a constrained model of asset management. With 6,452 bridges (over 20 feet long) in New Jersey, 2,584 state-owned bridges, and an average age of NJ bridges at 51 years, NJDOT is continually looking to innovate in order to meet their policy of maintaining an acceptability rate of 86% over the next 10 years. NJDOT was in need of a resource program that assists in advancing asset management practices, provides training in the use of advanced materials, technologies and construction techniques, identifies new technologies, and responds to unplanned, non-routine materials and construction issues.

2. Approach

The mission of Rutgers University's Center for Advanced Infrastructure and Transportation (CAIT) Bridge Resource Program (BRP) is to provide bridge engineering support to the New Jersey Department of Transportation (NJDOT)'s Bridge Engineering and Infrastructure Management Unit. The program is a partnership between federal and state transportation agencies and Rutgers University, which provides technical and educational services to address infrastructure needs in New Jersey. CAIT supports the NJDOT by providing staff and resources to address the most pressing bridge engineering and training challenges in New Jersey (through advanced materials development, design enhancements, construction improvements, evaluation, monitoring, data mining, management enhancement and support, and bridge research).

The overarching goal of the Bridge Resource Program is to achieve more effective asset management. This includes consideration and potential adoption of next generation assessment approaches to augment current reliance on qualitative condition metrics with more quantitative performance metrics. Although conventional engineering terms are used in this proposal to describe program services, the proposed tasks within each service will be focused on providing decision making assistance for concept development.

The primary objective of the Rutgers Bridge Resource Program (BRP) is to utilize the extensive laboratory and field testing equipment and staff expertise in Bridge Engineering to assist the New Jersey Department of Transportation's Bridge Engineering and Infrastructure Management Unit in developing bridge management system strategies, innovative materials, improved bridge design tools, advanced laboratory and field data collection, bridge monitoring strategies, bridge inspection, non-destructive evaluation and innovative technologies/equipment aimed at enhancing the state's bridge inventory condition by optimizing available capital resources.

The support from the UTC helped establish a program that is intended to become an integral component of the NJDOT's bridge research activities. During the period of this project, NJDOT approved the initiation of the first year of the Bridge Resource Program. This report outlines the effort undertaken during year one, including efforts supported by the UTC and NJDOT.

3. Methodology

Initial meetings with NJDOT provided a framework for the development of a resource program. The objectives of the program included:

1. Developing an annual report on the state's structural asset management activities as well as recommended improvements
2. Enhanced nondestructive evaluation (NDE) and inspection of state bridges including bridge inspection reports that provide recommended repairs
3. Advanced load rating modeling of state bridges including a technical report outlining the precise load carrying capacity of each structure
4. Technology transfer and training activities directed at improving the capabilities of NJDOT staff
5. On-call activities focused on responding to the department's needs beyond routine maintenance queries.

It was critical to form a partnership that responded to the department's needs. CAIT turned to consulting firms Michael Baker Jr and Intelligent Infrastructure Systems to field the initial Bridge Resource Program (BRP) team. In addition, the department identified SIMCO technologies as experts in materials science and concrete durability. To round out the team, CAIT reached out to Dennis Mertz, a renowned structural engineering professor and engineering consultant, to provide technical expertise.

The team proceeded to construct a workplan that addressed the department's needs, while providing flexibility to adjust as the program proceeded. The team opted to develop a generic scope that included a suite of technologies, along with a variety of technical reviews directed at resolving some of the department's most pressing needs. As a means of achieving the objectives, the team developed a list of tasks and subtasks, which were submitted to the department for their review and approval. As can be seen from the list of deliverables identified in Table 1, the team allocated up to twenty-two (22) bridge decks for evaluation using various techniques. In particular, up to ten (10) bridge decks were allocated for NDE and durability analysis, two (2) bridge decks were allocated for modeling and instrumentation, and ten (10) bridge decks were allocated for refined load rating. The intent was to provide NJDOT with a suite of technologies and methodologies that could be aimed at responding to the needs identified throughout the program year. During initial meetings following approval of the first year of BRP, NJDOT indicated their primary needs would be to evaluate the performance of High-Performance Concrete (HPC) in New Jersey, and to evaluate the effects of construction loading on highly skewed steel structures. In addition, as the program progressed, NJDOT contacted the BRP team to review other technologies, such as internal curing of HPC and mass concrete construction.

Table 1 - Bridge Resource Program Tasks and Deliverables

Task	Subtask – Deliverable
1. Enhance the NJDOT's Structural Management Activities	1a. In collaboration with NJDOTs Bridge staff, review the recent FHWA audit and provide guidance to improve asset management. Also, evaluate the setup and procedures currently used by NJDOT and provide specific guidance in using Version 5.2.2 for deterioration modeling of bridge assets
	1b. Develop a method to populate the cost data fields in Pontis® from the available cost data in TRNS-Port™, and populate the cost data for one year's worth of Bridge Construction Projects.
	1c. Develop and provide a prioritization model of structurally deficient bridges through a qualitative risk assessment that explicitly recognizes vulnerability, hazard and consequence of failure.
2. Provide Technology Transfer	2a. Utilize a comprehensive multimodal NDE scanning of up to ten (10) bridges with HPC decks to determine the "seriousness" of the deck cracking observed in HPC decks.
	2b. Develop and implement an instrumentation plan to better understand the stresses developed and "felt" by the bridge during the placing and curing of an HPC deck for two (2) bridges. Provide a report to the Department on the findings.
	2c. Perform a comparative field survey on a select existing and new bridge structures and evaluate the durability of reinforced HPC concrete and its consequence on the long-term performance of bridge decks.
	2d. Perform a refined load rating of up to ten (10) bridges that have resulted in Overload Truck Permits being re-routed due to load carrying capacity limits resulting from "standard" structural ratings to determine if additional load carrying capacity exists in the selected bridges and to demonstrate the value of such advanced analytical approaches.
	2e. Provide a synthesis report on methods to mitigate construction deformations in steel superstructure of skewed bridges.
	2f. Review technical publications, journals and other resources including but not limited to FHWA, UTC and TRB to discover new technologies and construction techniques. Present result in technical memorandums.
3. On-Call Services	3a. Respond to non-routine and non-planned structural management, materials and technology issues that arise throughout the year.
	3b. Develop Standards for new materials and construction techniques as selected by NJDOT from the technical memorandums developed in the Technology Transfer Task.

In order to respond to the tasks, subtasks and deliverables, the team has developed a chart (Figure 1) that demonstrates the envisioned project flow, expected outcomes/deliverables, and identifies task leaders and supporting members.

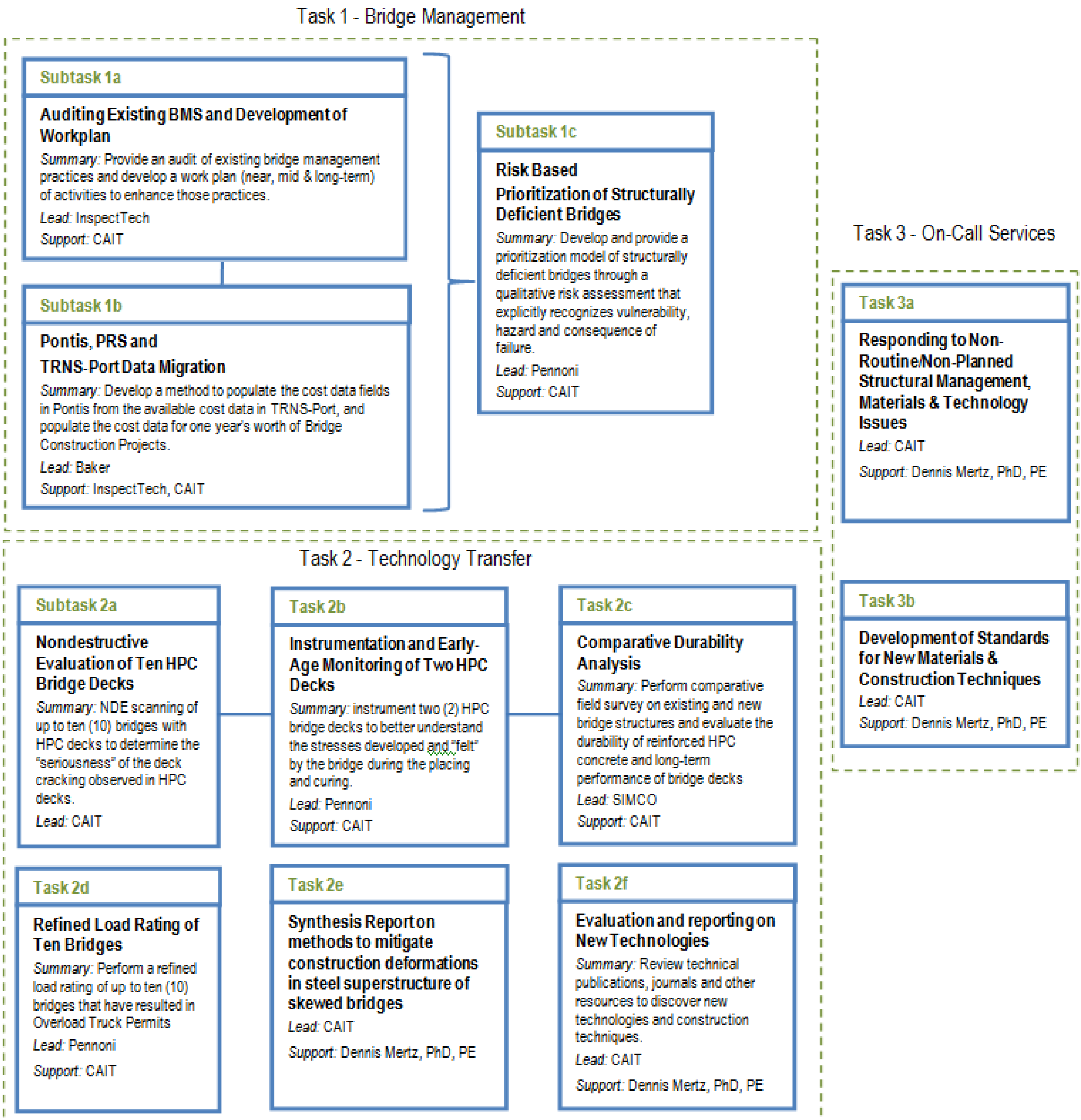

Figure 1 - Outline of tasks for the Resource Program

4. Findings

The intent of this grant was to develop the following products: a report on the state's structural asset management activities as well as a pilot plan to provide enhanced nondestructive evaluation and inspection on a sample of the State bridges. The success of this grant can be measured beyond the two initially anticipated deliverables. Upon inception, the program delivered immediate dividends to the department. A dump-truck fire on a major corridor, the NJ Turnpike, resulted in a bridge fire under a major east-west corridor, I-195. The program's rapid on-call response resulted in significant reductions in the corridor closing, which shortened the duration of congestions on the busy corridor. Similar examples of program successes are documented in the subsections below.

It should be noted that throughout the program, the team has found opportunities to leverage technologies and methodologies to address multiple needs identified by NJDOT. By doing so, the program has effectively and efficiently responded to NJDOTs needs, while managing its resources to maximize its ability to respond.

4.1. Bridge Management

The team identified three initial asset management tasks that can be initiated to better assist the department in their bridge management needs. The following is a brief explanation of each task, along with expected timelines for completion and outcomes/deliverables to be provided to NJDOT.

Bridge Management Software (BMS) deployment assistance

Initially, the team intended to provide NJDOT with an audit of the existing BMS and development of a workplan. During the contract negotiation process, FHWA conducted an audit of NJDOTs BMS and provided action items. As a result, the team redeveloped the scope of this activity to better serve the department.

The team is using its expertise and familiarity with the AASHTOWare Bridge Management software (formerly Pontis) to evaluate the setup and procedures currently used by NJDOT and provide specific guidance using Version 5.2.2 for deterioration modeling of bridge assets. The following activities are underway under this task:

- Review the recent FHWA audit and develop a clear understanding for the direction provided, including how the following were addressed. The review should include action items and overall guidance on applying modeling and programming capabilities of the software in a manner that fits with the way NJDOT needs to work.
    - Documentation available for users
    - Types of users that need access to the system and their relevant permissions
    - Software and overall IT configuration utilized by NJDOT

  - Data collected by NJDOT on bridges and where it is stored
  - Short, Intermediate, and Long-Term goals of NJDOT related to bridges
  - Relevant NJDOT performance metrics for bridges
- Develop a guide document to be used by NJDOT for the deployment and use of the new BrM 5.2.2 software. It should be noted that these tasks are dependent on AASHTO's release of the BrM 5.2.2 software. The guide will be used to provide users with a detailed reference (step by step), and provide guidance on items such as selecting the proper deterioration models based on DOTs needs/goals. Specific guidance will be provided in the following areas of the new software:
  - Planning
  - Deterioration (Key Focus)
  - Risk
  - Multi-Objective Analysis
  - Lifecycle Costs
  - Project Models
  - Dashboards
  - Corridor Planning

The team will focus on guidance in developing the following:

  - User-defined risk assessment types
  - NJDOT-specified deterioration scales and formulas
  - Setting NJDOT priority cost, assignment and programming of work
  - Interface for external work accomplishments
  - Alignment and integration with maintenance management systems
  - Creating a multi-objective framework to valuate specific interventions for a deteriorating bridge
  - Explain how utility can be used in terms of each sub-area
    - Mobility
    - Lifecycle Cost
    - Condition
    - Risk items
  - Explain how NJDOT can review/revise work candidates as they contribute to mobility, lifecycle cost, condition, and risk weightings
  - Step-by-Step guide to evaluating future condition at the detail and summary level
  - Development of the deterioration model logic

The team will develop a report outlining how to incorporate software solutions, including deterioration modeling, into the improvements recommended by FHWA in the audit. This report will contain the guidance on the use of the new software tools, specifically the deterioration modeling approach and procedures that can be used to better quantify the performance of New Jersey bridges. The purpose of this report will be to provide NJDOT with specific action items based on review of the audit and the team's knowledge and experience in the software arena. Recommendations will be general in scope, with methodologies and procedures remaining the focus. The goal of the document will be to provide NJDOT sufficient instruction to develop state-specific and element-specific deterioration modeling within the new software. The team will present these findings to NJDOT staff. The report will include the following sections:

1. Introduction and overview
2. Summary of
   a. Brief overview of current system – high level
   b. Summary of permissions and ways to improve security or setup
   c. Issues with software or IT configurations and improvement methods/recommendations
   d. Summary of where data is stored and possible ways to improve. Recommendations will include at least three and two will not be Bentley solutions. All solutions presented will consider Pontis' interaction with NJDOTs management software, TRANSInfo.
   e. Recaps of important metrics used by NJDOT
3. Guide to deterioration modeling, including examples to explain how data is sorted, parameters are chosen, and life cycles are reduced as results of the parametric modeling progresses based on user decisions. This will likely be based on the core AASHTOWare Bridge Management 5.2.2 guidance.

This task is currently being undertaken and is expected to be completed in 2014.

Cost Data Migration to PONTIS

Presently, NJDOT has a comprehensive Bridge Management System (BMS) which prioritizes bridge replacement, rehabilitation, deck and superstructure replacement, painting, scour retrofit, and other maintenance repairs. The BMS system is used to develop recommended funding levels to improve the condition of 'State maintained' bridges.

NJDOT has identified a need to prioritize, maximize available bridge funding, and provide decision makers with key construction cost data associated with bridge repair/replacement. Currently, NJDOT stores project and asset-related costs in their Trns-port™ system. To provide this cost information to NJDOT's BMS for analysis, the team is translating and arranging data into a format that can be imported into Pontis®.

To accomplish this goal, cost information from NJDOT's Trns-port™ system is being extracted, combined with data from the Capital Program Management's Project Reporting System (PRS), and transformed into a format that NJDOT's Pontis® BMS can utilize. To facilitate this transfer of data, the team is working with NJDOT staff to define the data structure and content required for the Pontis® BMS. This detail will act as the blueprint in which the team will follow for the remainder of the project.

Once a full analysis has been performed, the team will develop the transformation process to make the connection between cost, projects, and bridge structures, in a format that is consistent with Pontis® needs. This transformation process will be a one-time data migration, but will be fully documented so that future data updates can be streamlined.

This task is currently being undertaken and is expected to be completed in the beginning of 2014.

Risk-based prioritization

The objective of this task is to demonstrate risk-based prioritization through the application to a sample of structurally deficient bridges. Risk-based prioritization has been successfully employed in many fields that range from nuclear power to drinking water policy, and since the 2007 collapse of the I-35W Bridge this approach has been gaining attention related to the allocation of bridge repair, retrofit and replacement resources.

Through this application NJDOT is being provided with a framework that can be potentially incorporated within Pontis®. While the framework being developed is qualitative in nature, it has distinct advantages over condition or sufficiency rating-based approaches in that (a) it explicitly recognizes key performance limit states, (b) directly addresses bridge hazards, vulnerabilities, and exposures, (c) incorporates the uncertainty associated with various assessment techniques and provides flexibility for their implementation, and (d) provides a means to capture (in a useable format) expert knowledge and heuristics from top bridge engineers.

The team began the task by coordinating with NJDOT personnel to identify a sample of 100 structurally deficient bridges, shown in Table 2. For each of the sample bridges, the team reviewed at least the most recent two inspection reports as well as any design documentation available. Through this process a database that includes all of the requisite information needed to perform a risk-based prioritization on the sample of bridges was developed.

Table 2 - Structurally deficient bridges selected for risk-based prioritization

	Structure Number		Structure Number		Structure Number		Structure Number		Structure Number
1	114155	**21**	730152	**41**	1122150	**61**	1513153	**81**	2107156
2	202159	**22**	730192	**42**	1149160	**62**	1513154	**82**	2108155
3	203153	**23**	731154	**43**	1211152	**63**	1515150	**83**	2117160
4	206169	**24**	731156	**44**	1218154	**64**	1516152	**84**	2117161
5	206173	**25**	731157	**45**	1223153	**65**	1601162	**85**	2154160
6	209150	**26**	731160	**46**	1231168	**66**	1607161	**86**	3000163
7	214159	**27**	807152	**47**	1234173	**67**	1650161	**87**	3001151
8	220154	**28**	815150	**48**	1249165	**68**	1711156	**88**	3001176
9	221152	**29**	818151	**49**	1253164	**69**	1809150	**89**	917150
10	222153	**30**	821160	**50**	1304151	**70**	1809158	**90**	3000169
11	302151	**31**	823150	**51**	1308154	**71**	1817155	**91**	1409156
12	314151	**32**	905150	**52**	1309150	**72**	1817156	**92**	1105151
13	317155	**33**	906156	**53**	1310155	**73**	1904153	**93**	1850160
14	350162	**34**	907152	**54**	1337150	**74**	1922150	**94**	1850164
15	417158	**35**	908153	**55**	1409155	**75**	2003150	**95**	1850166
16	418163	**36**	1005151	**56**	1419169	**76**	2003166	**96**	2153161
17	510152	**37**	1007159	**57**	1426150	**77**	2101150	**97**	3000165
18	601152	**38**	1009150	**58**	1430153	**78**	2105152	**98**	3001159
19	722157	**39**	1014162	**59**	1502152	**79**	2105153	**99**	3001162
20	725171	**40**	1101163	**60**	1513152	**80**	2106151	**100**	3001175

Using the database developed, the team employed a series of different qualitative risk classification schemes and documented the sensitivity of the prioritization to these different schemes.

The culmination of this analysis is the calculation of Perceived Risk, which is defined as a function of Hazard, Vulnerability, Exposure, and an uncertainty premium. NJDOT elaborated that their approach to risk involved a review of reliability (a product of hazard and vulnerability) as a function of importance (exposure). Through this collaboration, the team is developing a report detailing the various prioritization schemes and the resulting outcomes. Following NJDOT review, the team will meet with NJDOT to discuss the findings and discuss (1) the usefulness of the various prioritization schemes, (2) areas were refinements are needed, and (3) the path forward (e.g. implementation within the BMS). This task is currently being undertaken and is expected to be completed by the end of 2013.

4.2. Technology Transfer

The Technology Transfer task was developed as an umbrella for a suite of activities and technologies that could be employed to respond to the department's needs. The team envisioned their use as either independent or combined to form robust experiments. The activities included literature searches, technical reviews of technologies, nondestructive evaluation of bridge decks, refined load rating, bridge deck instrumentation during construction, comparative analyses of bridge decks and other technologies.

As part of the effort and as mentioned in the Methodology section, the team allocated testing of a number of bridge decks for evaluation using various techniques. Once NJDOT indicated their need to better understand the performance of High-Performance Concrete (HPC) in New Jersey and understand the effects of construction loading on highly skewed steel structures, the team developed a testing program to complement these needs. The following subsections describe the work performed to respond to the department's requests.

High Performance Concrete evaluation

NJDOT began using HPC in the late 1990s and early 2000s. Throughout that period, NJDOT has had mixed performance with the material. The research bureau has undertaken a number of studies to better understand the material behavior, and recommend methods to improve performance. One hypothesis of the cause of deck cracking is self-desiccation and autogenous shrinkage in HPC. Nationwide, agencies have incorporated 3 to 14-day wet cure methods that begin immediately (up to 10 minutes after) final strike-off to provide curing HPC decks with sufficient moisture to prevent shrinkage cracking. While this has reduced the initial onset of plastic cracking, it has not resulted in conclusive proof that longer-term (28-365 day) cracking can be arrested using current practice.

NCHRP recently released a new synthesis report titled "High Performance Concrete specifications and practices for bridges", which documents a survey taken of state DOTs and is intended to help bridge owners, designers, contractors and material suppliers determine the appropriate specification requirements for HPC in bridges. In general, the report indicates that states vary in their means of specifying HPC and provides a list of changes in specifications and practices that have improved performance.

The team proposed a study that incorporated three technologies to provide the department guidance on the use of HPC in bridge decks:

1. Nondestructive evaluation (NDE) of bridge decks
2. Instrumentation and monitoring of bridge decks under construction
3. Comparative durability analysis of concrete

The main objectives the first proposed technology, condition assessment using nondestructive evaluation (NDE) technologies are to characterize cracks in HPC bridge decks and to evaluate their performance. The crack characterization by NDE is being concentrated on the measurement of crack depth, while the condition assessment of HPC decks is being concentrated on the evaluation of consequences of cracking on bridge deck deterioration progression. The study will be conducted on ten bridges with HPC decks.

A more objective condition assessment of bridge decks, than one relying solely on visual inspection, can be made by a complementary use of nondestructive evaluation (NDE) techniques. The condition assessment has three main components: assessment of corrosive environment and corrosion processes, concrete degradation assessment, and assessment with respect to deck delamination. The NDE technologies used in the assessment include: half-cell potential (HCP), electrical resistivity (ER), ultrasonic surface waves (USW), ground penetrating radar (GPR), and impact echo (IE) method. Each of the five techniques has its advantages and limitations. However, each of them can contribute to a more comprehensive assessment of the condition of a deck. In addition, since the data obtained from NDE surveys are quantitative, a more objective condition rating of bridge decks can be made. Different condition-rating schemes are being applied in the study.

The objective of the second proposed technology, instrumenting and monitoring bridge decks under construction, is to capture the in-situ, early age response displayed by high-performance concrete (HPC) decks due to the curing process. In particular, the goal is to capture and track the temperature profile, thermal strains (uniform and gradients), and shrinkage strains that occur during the curing process from initial casting through one month of operation (and longer if deemed necessary). Capturing the actual early age demands that HPC bridge decks are exposed to allows the identification (and potential ranking) of the causal effects related to early-age cracking. In addition, the quantification of in-situ early-age demands allows for the evaluation of various laboratory-scale specimens that could be used to further investigate the phenomenon and eventually underpin the development of a more robust HPC specification.

The objective of the third proposed technology, a comparative durability analysis of bridge decks, is to evaluate the benefits of using HPC for the construction of durable bridge decks exposed to de-icing salts, considering the impact of early-age cracking on long-term performance. The overall goal of the task is to characterize concrete on the basis of in-situ conditions, deck coring program, evaluation of new concrete deck construction, and using the data collected as input parameters in STADIUM® simulations to compare the service-life of HPC decks. The simulation program will include:

- The determination of representative exposure conditions on the existing HPC decks;
- Durability analysis of uncracked HPC decks, based on the concrete properties determined from the investigated structures;
- Durability analysis of *Class A* concrete decks, based on the properties of concrete mixtures with similar composition from the STADIUM® database.

The results of these simulations are being analyzed in view of the expected durability and service life expectations for both types of concrete.

To perform this suite of experiments, the team collaborated with NJDOT to develop initial criteria that would be used in selecting bridge decks to be tested. Table 3 highlights the bridges selected as of this writing, along with the initial selection criteria. In some instances, the department identified two structures (5a and 5b) that were of particular interest and importance. In other instances, the department could not identify bridge decks that met the selection criteria (decks constructed in a salt-environment, which did not experience early age cracking). Also note, the first two entries are new bridge decks that are used as samples for the instrumentation and monitoring bridge decks, NDE and comparative durability analysis activities. This task is currently being undertaken and is expected to be completed by the end of 2013.

Table 3 – Bridges selected for NDE and durability studies

Span #	Structure #	Description	Initial Selection Criteria
SPAN 1	0418151	Collings Ave over Route I-676 (Southbound)	New construction HPC (instrumented, durability, NDE tested)
SPAN 2	1601162	Route 3 over NJ Transit	New construction HPC with skew (instrumented, durability, NDE tested)
SPAN 3	0311150	Route 70 over Bisphams creek	2-5 yr old HPC (durability and NDE Tested)
SPAN 4	1234-509	Smith Street (CR 656) over State Route 440	2-5 yr old HPC (durability and NDE Tested)
SPAN 5a	0511156	RT 52 bridges over Rainbow Channel (RT 52 Causeway)	2-5 yr old HPC (durability and NDE Tested) – salt environment and early-age cracking
SPAN 5b	0511157	RT 52 bridges over Elbow Channel (RT 52 Causeway)	2-5 yr old HPC (durability and NDE Tested) – salt environment and early-age cracking
SPAN 6		Not Chosen	2-5 yr old HPC (durability and NDE Tested) – salt environment but no early-age cracking
SPAN 7	1209155	Route 9 Edison (Northbound)	5-10 yr old HPC (durability and NDE Tested)
SPAN 8	1209156	Route 9 Edison (Southbound)	5-10 yr old HPC (durability and NDE Tested)
SPAN 9	3100-001	Ocean City – Longport Bridge	5-10 yr old HPC (durability and NDE Tested) – salt environment and early-age cracking
SPAN 10		Not Chosen	5-10 yr old HPC (durability and NDE Tested) – salt environment but no early-age cracking

Construction effects on severely skewed steel structures

At the time of erection, steel girders in highly skewed bridges can deflect out-of-plumb due to differential deflections experienced at crossframe connections. The expectation of the girders is that upon concrete placement, the girders will deflect back to a plumb configuration. Erecting steel girders for severely skewed bridges require special consideration. AASHTO 6.7.4 requires for bridges with a skew greater than 20 degrees, that crossframes be installed normal to the main members. The National Steel Bridge Association (NSBA) Steel Bridge Design Handbook states that this practice results in large differential deflections between each end of the crossframes. It further suggests that special guidance should be provided to the fabricator and erector. NSBA indicates that crossframes and diaphragms tend to equalize deflections, further cautioning that designing the interior and exterior girders for different inertias and dead load deflections can result in significant differences in camber between girders. The amount of differential camber, which is attributed to the effect of the bridge skew, the design camber plus allowable fabrication variances can be on the order of 2 or 4 inches on highly skewed bridges in the crossframe lines closest to the support locations. The effect of this differential camber during construction needs to be considered by the designer since the differences will likely complicate girder fabrication and erection. However, according to available literature out of plane bending of girders may not be a long-term concern.

NJDOT expressed interest in research focused on understanding the effects of highly skewed bridges, and developing recommendations for design, fabrication and erection of these structures. The team will review available literature on highly skewed bridges to identify the latest analyses and research as well as study contractors' means and methods for girder erection in these complex structures and fabricators diaphragm connection detailing to determine the impact that these variables may have on out-of-plane bending. A synthesis report will be provided outlining the results of the literature review, means and methods review, and discussions with fabricators and erectors.

In addition to a synthesis report, the team allocated two (2) bridges from the refined load rating activity to be used in a parametric study of the construction effects on severely skewed steel superstructures. The overall goal of instrumenting and monitoring steel girder frame superstructures on bridges with severe skew is to capture the in-situ, construction-stage response displayed by steel girders during erection and concrete deck construction. In particular, the goal will be to capture and track strains that occur during the erection and deck placement process from erection through initial casting (and longer if deemed necessary). Capturing the actual construction demands that steel girders are exposed to will allow the identification (and potential ranking) of the causal effects related to erection and construction.

This task is currently being undertaken and is expected to be completed by the end of 2013.

Refined load rating

The objective of this task will be to perform refined load ratings of eight (8) bridges through the integrated use sensing and simulation. While there are few (if any) bridges owned by the NJDOT that are currently posted, there are several bridges that force Overload Truck Permits to be re-routed due to load carrying capacity limits resulting from "standard" structural ratings. To examine the validity of these restrictions, the research team will employ 3D finite element (FE) modeling, load testing, and model-experimental correlation to determine if additional load carrying capacity exists in the selected bridges. In addition to potentially alleviating constraints on the movement of overload vehicles, this task will expose NJDOT personnel to "best practices" capacity estimation techniques and will demonstrate their value. Table 4 provides a listing of the bridges selected for this study. This task is currently being undertaken and is expected to be completed by the end of 2013.

Table 4 – Bridges selected for the Refined Load Rating study

Span #	Structure #	Description	General Observation
SPAN 1	0118150	US Route 206 over Cedar Branch	Multi-span solid slab structure
SPAN 2	0324152	US Route 206 over Springers Brook	Single-span monolithic reinforced concrete T-beams
SPAN 3	1103152	US Route 1 over D&R Canal	Single-span solid slab with monolithic stiffening ribs on a severe skew
SPAN 4	1512152	NJ Route 72 over Mill Creek	Two-span continuous reinforced concrete three-sided culvert on a severe skew
SPAN 5	1516152	NJ Route 166 over Toms River	Two-span continuous monolithic reinforced concrete T-beams
SPAN 6	1701151	NJ Route 40 over West Branch Creek	Single-span hybrid structure consisting of fully-encased steel beams and prestressed adjacent box beam structure on a skew
SPAN 7	1703152	NJ Route 40 over Salem Creek	Single-span hybrid structure consisting of fully-encased steel beams and partially-encased steel beam structure
SPAN 8	1237155	NJ Route 18 over Raritan River	Hybrid Structure - Main span is a fracture critical, curved steel, two-girder bridge system on piers with skewed supports

Webinar Training

NJDOT requested the program provide structural engineering and analysis training via webinars provided by ASCE. BRP staff coordinated twenty (20) webinar sessions throughout the program year. The following is a listing of the webinar courses provided for NJDOT staff:

1. Friday, November 30, 2012, 12pm-1pm - Culvert Analysis Using FHWA HY8 Software
2. Wednesday, December 05, 2012, 11:30am-1pm EST – Preventing Bridge Damage During Earthquakes
3. Tuesday, December 11, 2012, 11:30am-1pm - LRFD Design of Ground Anchors & Anchored Wall Systems
4. Wednesday, December 12, 2012, 11:30am-1pm EST – Strengthening Structural Steel Beams
5. Monday, December 17, 2012, 11:30am-1pm EST - Verification of Computer Calculations by Approximate Methods
6. Thursday, December 20, 2012, 11:30am-1pm EST – Geosynthetic Reinforced Mechanically Stabilized Earth Walls
7. Monday, January 07 and 24, 2013, 11:30am-1pm EST – Load and Resistance Factor Design (LRFD) for Geotechnical Engineering Features (Two Part Series)
8. Thursday, January 10, 2013, 11:30am-12:30pm EST - Earthwork 101
9. Friday, January 11, 2013, 11:30am-1pm EST - Practical Design of Bolted and Welded Steel Connections
10. Tuesday, January 22, 2013, 12pm-1pm EST - Advanced Bridge Hydraulics with HEC-RAS
11. Friday, January 25, 2013, 11:30am-1pm EST - Underpinning & Strengthening of Foundations
12. Wednesday, February 06, 2013, 12pm-1pm EST – The Five Pieces of Equipment Every Bridge Inspector Should Have
13. Thursday, February 7, 2013, 11:30am-1pm - Energy Piles: Background & Geotechnical Engineering Concepts
14. Tuesday, February 12, 2013, 11:30am-1pm - LRFD for Geotechnical Engr. Features: Design & Construction of Driven Pile Foundations
15. Friday, February 15, 2013, 11:30am-1pm EST – Avoiding Failures of Retaining Walls
16. Friday, February 22, 2013, 11:30am-1:30pm - Design of Anchor Bolts
17. Monday, February 25, 2013, , 11:30am-1pm - Design of Concrete Embedments
18. Monday, March 4, 2013, 11:30am-1pm - LRFD for Geotechnical Engr. Features - Deep Foundations - Lateral Analysis
19. Monday, March 18, 2013, 11:30am-1pm EST – Corrective Work in Steel Structures
20. Thursday, March 28, 2013, 11:30am-1pm EST – Design for Extreme Event Loading

4.3. On-Call Services

The intent of this on-call task is to rapidly respond to the State's needs beyond routine maintenance queries. The advanced forensics and Nondestructive Evaluation techniques being developed and refined at CAIT can be leveraged to provide advanced monitoring of NJ assets and to diagnose complex conditions that are undetectable using visual inspection practices. As a result, the NJDOT will be able to leverage advanced techniques, when needed, to perform highly specialized evaluations of state assets for planning maintenance strategies.

The BRP staff will respond to 90% of requests within one day and develop an appropriate work plan. For evaluation requests, BRP staff will review existing conditions, determine the appropriate method of evaluation, perform the needed evaluation and recommend improvements. Infrastructure Condition Monitoring Program (ICMP) will respond to NDE field evaluation upon NJDOT request within 3 days. For materials and technology review requests, BRP staff will review available resources such as FHWA, TRB and other publications, determine the viability of the materials and/or technology and provide a recommendation within 3 days.

In addition, the team developed a framework for NJDOT to select from technologies and/or construction techniques identified under task 2 for field application. BRP staff will develop technical standards, including construction inspection techniques, materials requirements, tolerances, and other key parameters sufficient in detail for inclusion in construction projects.

Development of these standards may include a number of ancillary activities, such as reviewing existing NJDOT standards, details and guides for conformance with the new technology or construction technique. For those standards, details and guides that may need revision, BRP staff will prepare recommended revisions to the standards/details that would allow for a cost-effective implementation of the new material or construction technique.

NJDOT may also request a review of specific standards, details and guides for updating based on new materials, construction techniques or improved details. BRP staff will coordinate the revisions with NJDOT staff and prepare documents reflecting the revisions.

The following subsections provide a summary of activities undertaken under the on-call task.

I-195 dump truck fire response and analysis

In response to a dump-truck fire under the I-195 Bridge over the NJ Turnpike, the team performed a rapid load testing of the structure to determine the remaining load capacity in terms of its ability to carry traffic prior to its demolition, scheduled approximately 8-weeks from the time of testing. The team performed testing on October 11, 2012, provided initial observations and recommendations to reopen the bridge on October 16, 2012; and provided a detailed report of the team's findings on November 7, 2012.

Mass Concrete

NJDOT requested that Rutgers-CAIT perform a literature review on the state-of-the-art practice of mass concrete and use the findings to compare with the Thermal Control Plan for the Route 7 Wittpenn Bridge Pier 1W cap as well as the current mass concrete specifications included in the NJDOT 2007 Standard Specifications. The review focused on material composition, with description of each component’s contribution to heat of hydration. The team observed that the literature focused on two areas of concern, maximum temperature reached during curing and thermal differentials between the core and surface of the mass concrete element.

The literature has extensively documented the urgency of maintaining the maximum curing temperature below 160°F. The adverse effects associated with exceeding the maximum temperature threshold are severe, but not visible for months or years after construction. This threshold should never be exceeded.

The literature also documents damages resulting from exceeding temperature differential thresholds, which are more immediate and can be identified during construction. The thermal-induced cracking that results may be repaired through industry accepted means, from seals, coatings for hairline cracking, to more comprehensive repairs.

During early stages of curing, the concrete has not developed sufficient strength to resist excessive thermal gradients. Thus, form insulation and other methods to protect the concrete surface from dissipating heat greatly or reach excessively high peak temperatures reduces the likelihood of deleterious effects. The results of this literature review suggest that current research and industry agree that temperature thresholds are critical to mass concrete. Proper controls must be established in order to ensure well-performing concrete elements to be constructed.

Internal Curing of High Performance Concrete

Rutgers Center for Advanced Infrastructure and Transportation (CAIT) is performing a study of High Performance Concrete for NJDOT under the 2012 Bridge Resource Program. In concert with studying existing bridge construction practices, CAIT is reviewing research papers and ongoing studies to identify potential technologies that may be incorporated in the state to improve HPC performance.

Recently, research in the practice of internal curing to reduce/eliminate cracking in concrete has resulted in successful implementation in new bridge construction. Studies by NIST, ACI, TRB and NCHRP have referred to the practice as promising. The following outlines the team’s current findings and provides proposed steps to further study/demonstrate the construction practice.

Internal curing is a relatively new technique of casting concrete that includes the replacement of a portion of fine aggregate with an equivalent volume of pre-wetted fine aggregate. The result is a concrete mixture with a “reservoir” of moisture locked-in to be drawn upon once the concrete begins to shrink or self-desiccate.

New York State has taken initial steps to demonstrate the performance of internally Cured HPC (ICHPC). In the report, “Field Performance of Internally Cured Concrete Bridge Decks in New York State” (SP-290-7, Streeter et al), NYSDOT reports HPC-IC has shown improvements by reducing the cracking associated with concrete shrinkage. Seventeen (17) bridges were included in the study. The report concludes that ICHPC is a helpful tool that can be used to improve concrete properties, but it must be coupled with sound construction practices.

The team is currently developing a draft construction specification for internal curing of concrete for NJDOT. This task is currently being undertaken and is expected to be completed by the end of 2013.

5. Conclusions

BRP has provided opportunities to bring technologies to the department, review existing practices, and propose the use of new construction techniques to improve asset management, design and construction practices. In addition, it has created a new channel of communication between CAIT and NJDOT that allows for the rapid deployment of innovative technologies. In the future, the BRP is envisioned to continue to identify opportunities for innovation. It is anticipated that new research topics will be borne out of the program. As research is completed, it can return back to the BRP for pilot testing and recommendation for deployment. The cycle of innovation, testing, implementation and need for further innovation can be perpetuated through the creation of similar resource programs. The inauguration, progress and resounding success of this new program could not be possible without the support of the University Transportation Center (UTC) Grant, New Jersey Department of Transportation and the Federal Highway Administration – New Jersey Division office.

6. Recommendations

The team is currently in development of a proposal for the second year of the BRP. The team has worked with the department to identify priorities for the upcoming year and has established a similar framework to the one described in this report. As the program matures, the team anticipates developing protocols that can fuel innovation in state departments’ of transportation procedures. The reports developed through this program will be posted in the CAIT website and open for the public to review. It is highly recommended that other states review the program reports and consider similar relationships with UTCs.

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