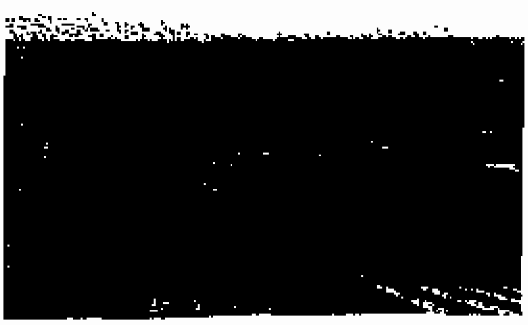
Rhode Island Department of Transportation

Structural Design Program Review Report

CY 2006



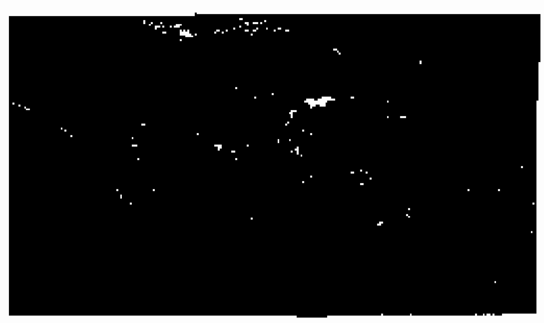


Table of Contents

FHWA Structural Design Program Review -
Rhode Island Department of Transportation

I. EXECUTIVE SUMMARY

A. INTRODUCTION

The Federal Highway Administration conducts Structural Design Program Reviews to document and transfer the best structural engineering program practices to State Highway Agencies (SHAs) across the country. Reviews of SHA structural engineering programs are requested by SHAs and FHWA Division Offices. Through the implementation of the Structural Program Review, the FHWA will document the best structural engineering practices, policies and procedures, recognize areas of excellence, and identify opportunities for advancement and improvement. By assessing the program practices of individual SHA bridge programs nationwide, the FHWA will be able to address structural engineering program needs and more effectively transfer successful practices and technologies. A separate report of best practices from all of the State reviews that are conducted annually will be disseminated nationally. Goals and benefits of the NSEIP include:

- Provide SHAs a service to benchmark their program against the state-of-the-practice
- Share information on innovative practices, procedures, processes, and technologies in design and construction to encourage deployment of best practices
- Identify SHA structural design program needs to assist in the formulation of national FHWA program goals for bridge program technology delivery and technical assistance
- Provide opportunity for peer exchange
- Continually improve partnership between SHAs and FHWA

The Rhode Island Department of Transportation (RIDOT), in cooperation with the FHWA Rhode Island Division Office, requested a review of their structural design program in early 2006. A team of FHWA specialists, along with the State Bridge Engineer, Delaware Department of Transportation, conducted formal interviews with RIDOT design staff and specialists to identify best practices and needs in the RIDOT structural design and construction program between September 25 and 27, 2006. The findings of the personnel interviews and assessments of documented procedures and policies that followed the interviews are contained in this Executive Summary and Final Report. The main objectives of the Rhode Island DOT review were:

- Identify and document best practices that may help other SHAs improve the efficiency and cost-effectiveness of their structural engineering programs;
- Provide recommendations to RIDOT to improve existing practices and procedures, improve efficiency and cost-effectiveness, and maintain structural engineering capabilities.

The intent of this report is to provide the Rhode Island DOT a record of the findings of this review and to offer recommendations for improvement based on best practices that are implemented by State agencies nationwide. Appendices referenced in the report are attached to the formal file copy of the report and Recommendations for Improvement are provided only to RIDOT.

B. RECOGNIZED ACHIEVEMENTS

The review team identified several practices that are deployed by the RIDOT Bridge Design office that serve as exceptional practices to showcase to SHAs across the country. We wish to commend RIDOT for these noteworthy achievements. A brief summary of the policies, procedures, and practices that were recognized as best practices in RIDOT's structural design program are provided in the executive summary.

Summary of Best Practices

'Constructability' Evaluation of Bridge Design Projects throughout Project Development
RIDOT places a special emphasis on the importance of reviewing the 'constructability' of bridge design projects, from project initiation, throughout the life of the design project. Bridge erection and constructability reviews are performed by the RIDOT project manager, along with the consultant designer, at prescribed stages throughout the development of the project. These reviews are thought to have success at reducing construction claims and may partially account for the success the RIDOT has had to achieve excellent estimates of bid prices on construction projects.

Rhode Island DOT Bridge and Materials Research Program
RIDOT implements a relatively low-budget structural and materials research program that has delivered high 'pay-off' program and facility improvements. Some examples of successful applied research include:

Statewide Implementation of HPC – RIDOT uses high strength, low permeability concrete on most structural elements throughout the State. The main goal for implementing HPC is to reduce bridge element deterioration. Research has indicated a significant long-term benefit in bridge element durability for a modest initial cost increase.

Systematic use of Concrete Sealers to prevent bridge element deterioration – As a result of their research program, RIDOT reduces deterioration of bridges throughout the state, with the application of concrete sealers on bridge elements that are exposed to deicing salts.

Implementation of 'Metalizing' and weathering steels to improve the durability and reduce maintenance of steel structures – The Department commonly uses weathering steels for bridge superstructures and has also used metalizing to extend the life and reduce maintenance costs of steel structures.

Routine Use of MSE and Modular Block Retaining Walls – RIDOT commonly utilizes Mechanically Stabilized Earth and Modular Block retaining wall systems throughout their highway network, successfully implementing wall technologies that greatly reduce initial and life-cycle costs over conventional cast-in-place retaining walls.

Successful Implementation of Value Engineering on Major Bridge Projects – Although RIDOT does not have a formal policy for the implementation of value engineering, on several bridge projects, particularly major bridge projects, the implementation of value engineering has resulted in controlling construction costs.

Bridge Washing – One particular preventive maintenance strategy that has been especially effective for maintaining bridge decks and superstructure systems is the implementation of a program of "pressure-washing" bridge components. This strategy is preformed systematically and state-wide as a means to extend the service life of bridges and enables more thorough bridge safety inspections.

Accurate Estimates of Bid Prices on Construction Projects - RIDOT has been able to maintain cost estimates for bridge and highway projects within 5% of actual bid costs. This is an exceptional result and the means for this lies partly within their process for emphasizing the review of constructability during the scoping, development and design phases of projects.

C. <u>RECOMMENDATIONS FOR IMPROVEMENT</u>

As a result of our review of RIDOT policies and practices and during interviews with Department staff, suggestions to improve the RIDOT Structures Design program were generated. The FHWA Bridge Program offices will evaluate these recommendations and determine where FHWA can provide assistance, and develop tools to support RIDOT needs. The following recommendations are made for your consideration as suggestions that will improve performance in the RIDOT Structural Design Program.

It should be noted that some of these findings are systemic problems of proportion which we typically do not encounter with the FHWA Structural Design reviews and reflect that the RIDOT structural design program is currently less effective than the structural design programs in most other State Highway Agencies. Many of the design program process deficiencies that were identified, as compared against other States processes, were not only noted by the review team, but the deficiencies were validated, during interviews with the Bridge Office staff. The engineering staff was nearly unanimous in recognizing and outlining the deficiencies that currently exist within the Bridge Design office program. We recommend that these problems be addressed with a great sense of urgency as the technical capabilities and oversight on structural projects is severely impacted by these program deficiencies. The oversight of RIDOT highway bridge projects are compromised, and the quality of the structures and foundations are in question, when staff engineers are not able to maintain adequate levels of technical expertise to guide and control the bridge design process.

Finding:

1. The RIDOT Bridge Design program staff lacks basic levels of engineering expertise and does not have adequate procedural control to perform the role to effectively oversee the quality and safety of bridge design products. One hundred percent of all bridge design, geotechnical engineering, and hydraulic engineering tasks are completed by consultant staff. There is no formal independent quality assurance or quality control program that RIDOT implements to assure that bridge elements are designed safely, efficiently and in accordance with AASHTO design provisions. In several instances, due to the lack of in-house expertise, the RIDOT has even used consultant services to generate design guidelines and policies that the owner uses to direct consultants, such as the recently drafted RIDOT Bridge Design Manual. The RIDOT does not have sufficient technical expertise to develop the State's design policies and guidelines. Additionally, RIDOT engineers serving in the role of project manager, often have their authority to oversee the design of structural elements challenged by consultant design engineers due to their perceived inability to interpret and apply continually evolving design standards. The extent to which the RIDOT staff has indicated their lack of understanding and application of design standards in routine and major bridge, foundation and hydraulic design suggests that the RIDOT is not achieving the intended level of oversight that is required as part of the FHWA/RIDOT Oversight Agreement for Federal-Aid Projects.

Recommendation: A SHA Bridge Design office must adequately control and oversee design products and services that result in highway projects that are utilized and funded by the traveling public. Staff members must make important oversight decisions, provide direction to consultants regarding the implementation of evolving design standards and unique bridge details, monitor the quality and cost-effectiveness of bridge designs, and maintain policies that ensure quality is delivered in consultant products. For this reason, staff engineers need to be experienced in the design procedures and practices that are utilized by consultants and they must be able to understand and apply regularly updated design provisions to understand the impacts of new design provisions on the final design. As a minimum, a representative sample of structures, foundations and walls should be designed, in-house, or a comprehensive process review program should be established and implemented by RIDOT staff to maintain the necessary level of expertise needed to ensure safe and cost-effective designs are being delivered by consultants. Staff engineers need to have access to up-to-date tools and be assigned common design process work sufficient to maintain a level of expertise needed to provide QC/QA. RIDOT should develop and implement a formal business or quality control plan for structural elements to define quality indicators in the bridge design process. The design process measurements defined in those plans should be routinely measured and attained by in-house staff.

The Delaware Department of Transportation's bridge design program can serve as an example of how one State effectively maintains in-house technical expertise to oversee consultant services and products, and manage and maintain the owner's policies and procedures. The Delaware bridge office has a staff of 18 members, including 15 engineers. Three of the 15 engineers serve as managers. The Delaware Bridge Design office designs 70% of bridge projects, in-house. Those projects represent 30% of the total projects in terms of construction costs (i.e., many of the smaller bridge projects are designed in-house). Consultants are awarded contracts to deliver 70% of bridge designs, in terms of construction costs. Each in-house design engineer typically is responsible for one bridge project under construction, the design of one bridge project, and the early scoping and development of one bridge project, in addition to reviewing one consultant project. One of Delaware's bridge design staff serve as a full-time reviewer of consultant projects, and squad managers often serve as project managers to review consultant designs for bridge design projects that are considered major projects. Members of the entire staff are able to serve on State standards, specifications and guideline development teams, in-house, to prepare and maintain all of the State's structural, geotechnical and hydraulic design and construction program policies.

Finding:

2. The RIDOT Bridge Design currently does not have a specialist assigned to be expert in geotechnical and hydraulic engineering, which is essential for the oversight of safe and cost-effective foundation and wall design and scour evaluation. The RIDOT relies on consultants for these services and has no expertise or systematic program in place to measure the adequacy or efficiency of geotechnical and hydraulic analyses. We know of no SHA that does not have staff that is dedicated to maintain state-of-the-art expertise in foundation and hydraulic design in order to perform effective QC/QA of consultant design products and develop guidelines and policies to direct consultants to implement the desired design practices.

Recommendation: Based on projected levels of design work that is required in the next 3 to 5 years, the RIDOT should immediately establish how many specialists are necessary to direct and oversee the geotechnical and hydraulic design services (i.e., perform quality control) that are awarded to consultant engineers and to establish and maintain existing Departmental procedures for the design and analysis of foundations, walls and hydraulic features. In this respect, as is the case with structural design, the RIDOT does not have adequate expertise or up-to-date tools to measure the quality or cost-effectiveness of bridge and foundation design features. A representative sample of foundations should be designed in-house, or rigorously reviewed to ensure that State practices are adequate and foundation designs, performed by consultants, are in conformance with State and AASHTO design criteria. Likewise, a hydraulic analysis specialist should be part of the Department's staff to ensure that designs are in conformance with prevailing hydraulic standards.

To follow-on from Recommendation no. 1, the Delaware DOT's 13 bridge design engineers acquire and maintain expertise in hydraulic and geotechnical engineering as a result of routinely performing hydraulic analyses and foundation designs for specific bridge projects. The staff engineers are able to technically evaluate consultant hydraulic and foundation design computations and findings and are capable of establishing and maintaining Departmental policies regarding evolving foundation and hydraulic design criteria.

Finding:

3. RIDOT currently outsources nearly all engineering services. The Bridge Design office is now responsible for implementing a new project tracking and control system that serves as a vehicle to schedule and manage project deliverables. The RIDOT Bridge Design office engineers expressed that they are serving most of their time in an administrative role that is not well defined and is focused on overseeing product delivery and construction schedules, at the expense of overseeing product quality and safety. RIDOT engineers do not have systematic processes in place to evaluate bridge element design quality, safety and cost-effectiveness. The administrative process changes that the Department has implemented have greatly diminished the staff's hands-on involvement and understanding of specific project design requirements, leading to a lack of control and ownership of Departmental design processes. In several instances, consultants are now challenging the authority of RIDOT project managers to question/review design products, processes and computations. The FHWA review team heard directly from many of the staff that they are not being empowered to perform substantive design work. For this reason, their level of design expertise gradually diminishes and they are unable to provide a quality control or oversight function for many design processes.

Recommendation: RIDOT should foster improved communication between bridge design, inspection, construction, research and management personnel to ensure the staff has a clear vision of the primary structural design program objectives. These internal program objectives and roles should be documented. In addition to ensuring design office staff has a better understanding of the Departmental goals, internal program objectives should be geared to provide staff with more responsibility and authority for making decisions to oversee and develop quality design products. Many SHAs provide staff engineers formal opportunities to meet regularly amongst themselves and management to pursue program and process improvements. These meetings serve to ensure the Department is consistently and uniformly meeting business plan and quality control plan objectives. Each design engineer that is responsible for product safety and quality oversight should have an opportunity to discuss technical training, mentoring and succession training needs.

Finding:

4. Key guidelines and policies for structural, geotechnical and hydraulic design for routine and major bridge projects are not being developed by in-house personnel, but by consultants who have technical expertise in matters to which the guidelines and policies apply. Hence, the guidelines and policies are being generated by those that are to be directed by the policies. A primary example is the development of the recently drafted RIDOT Bridge Design Manual for implementing LRFD. Additionally, the updates to

standard drawings and details are often out-sourced to consultants due to the lack of in-house capabilities to operate CADD systems.

Recommendation: All guidelines, policies and programs that are utilized by RIDOT to assess the efficiency and effectiveness of design products should be developed by in-house staff. This will ensure that the owner is in control of the product as required by the RIDOT/FHWA oversight agreement by ensuring that key staff members understand and learn the impacts of new and continually changing processes and design standards that the owner requires the contractor to apply. Furthermore, specific quality and safety feature review steps for the owner's quality control of design and PS&E plan review should be clearly defined, documented and tracked to ensure that these quality assurance checks are being consistently applied.

Finding:

5. Consultants often have the responsibility for initiating and defining project requirements. The consultant is currently responsible for all aspects of project scoping prior to RIDOT staff involvement. This illustrates that RIDOT is not controlling project definition and project managers are relegated to commenters.

Recommendation: We strongly recommend that RIDOT project managers initiate and define initial project specific needs, prior to awarding the project to a consultant. Furthermore, the project manager should then have complete control and authority on project level matters.

Finding:

6. Currently, the consultant procurement process requires that consultants be evaluated on a project-by-project basis. This means that there are many superfluous and redundant reviews of consultant qualifications.

Recommendation: The consultant procurement process could be streamlined and made more efficient. For example, pre-qualifying consultants would eliminate the need to repetitiously re-evaluate consultants for each design proposal they submit.

II. REVIEW FORMAT

The review was conducted by examining RIDOT procedures, standards, and other references related to structural design produced by the RIDOT Bridge Design Office after a three-day visit to interview RIDOT specialists. The review team conducted personal interviews with 12 RIDOT managers and engineers in the Bridge Design, Research, and Contract Administration offices. RIDOT Bridge office staff completed an 18-page survey with amplifying questions on policies, procedures, and design issues used to control work within the Bridge Design program office, prior to the interviews. The State Bridge Engineer from the Delaware DOT participated in the interview sessions along with three FHWA bridge specialists to define policies, procedures and products that exemplify best practices. The following is a list of the RIDOT personnel that were interviewed.

RIDOT Specialists Interviewed

Dave Fish, Bridge Managing Engineer
Bob Fura, Chief Civil Engineer
Colin Franco, Research and Technology Managing Engineer
Georgette Chahine, Principal Civil Engineer
Robert Faraj, Senior Civil Engineer
Rahmat Noorparvar, Principal Civil Engineer
Michael Savella, Principal Civil Engineer
Andranik Tahmasian, Principal Civil Engineer
Patrick Vu, Pontis and Consultant Inspection Manager
Marc Bruneau, Bridge Inspection Manager
Lee Perkins, Bridge Management System Manager
Kazem Farhoumand, Deputy Chief Engineer

A close out meeting was held with Mr. Kazem Farhoumand, Deputy Chief Engineer, and Mr. Dave Fish, managing Bridge Engineer, on September 27, 2006. At that meeting, the preliminary findings of the review were presented. Following the closeout meeting, a number of documents that were collected during the interviews were examined. The information gathered from the program review survey, the formal interviews, and the review of the documents make up the basis for this report. The following list includes the RIDOT documents and procedures that were examined as part of this review. Copies of these documents are on file and available for review upon request.

Reference List of RIDOT Documents Reviewed

Structures Design Office Organizational Charts
RIDOT Bridge Design Manual (BDM), 2006 Draft Edition
TAC -0002 (DPM 460.01) – Instruction for the Preparation of Contract Specific Documents
TAC -0006 (DPM 410.04) – Context Sensitive Solutions
TAC -0012 – General Note Regarding Temporary Construction Conditions
TAC -0025 – Tracking Consultant Requests for Contract Changes
TAC -0022 – RI Standard Specifications for Road and Bridge Construction, 2004 Edition
TAC -0030 (DPM 460.09) – Advertising Process
TAC -0037 (DPM 450.02) – Plans Content Requirements
TAC -0038 – Plans, Specifications, and estimate Submissions
TAC -0042 – RI Standard Specifications for Road and Bridge Construction, 2005 Edition
DPM 230.05 – Monthly Progress reports for Consultant Contract Monitoring
WBS 1.15 – Bridge Type Study Report
WBS 3.03 – Final Bridge Plans
RIDOT/FHWA Oversight Agreement for Federal-Aid Projects

III. RECOGNIZED ACHIEVEMENTS

The following achievements are policies, procedures, and practices that were recognized as being best practices in RIDOT's structural engineering program.

'Constructability' Evaluation of Bridge Design Projects throughout Project Development

RIDOT places a special emphasis on the importance of reviewing the 'constructability' of bridge design projects, from project initiation through construction of the project. Bridge erection and constructability reviews are performed by the RIDOT project manager, along with the consultant designer, at prescribed stages throughout the development of the project. The reviews are performed at 10%, 30% and 90% stages of completion. These reviews are thought to achieve excellent estimates of bid prices on construction projects. RIDOT project managers also attend public hearings, pre-construction meetings and visit the construction site throughout the project to evaluate the incorporation of bridge elements in construction.

Rhode Island DOT Bridge and Materials Research Program

RIDOT implements a relatively low-budget ($200-$300M annually for all Department research) structural and materials research program that has delivered high 'pay-off' program and facility improvements. Approximately 4 to 5 projects are funded annually and 2 or 3 are conducted in-house. On occasion, RIDOT works with a New England research consortium to pool research funding for large projects. One primary structural research contact operates a modest research lab staffed with 3 engineers and 3 technicians. Some examples of successful applied structural research include:

Statewide Implementation of HPC – RIDOT uses high strength, low permeability concrete on most structural elements throughout the State. The main goal for implementing HPC is to reduce bridge element deterioration. Research has indicated a large long-term benefit for a modest initial cost. The permeability of 2000 coulombs is a target for deck and substructure concrete. Recently, polypropylene fibers have been used to control shrinkage cracking on one bridge project. A variety of admixtures have been investigated and used to control shrinkage cracking. Pozzolans such as fly ash and slag may replace up to 40% of the cementitious material (and as high as 60%) in some mix designs. An extensive effort to evaluate curing techniques was also conducted and the construction specifications have been updated with the best methods for wet cure.

Systematic use of Concrete Sealers to prevent bridge element deterioration – The majority of RIDOT structural research efforts are to investigate methods through applied research to reduce bridge deterioration. These methods are then applied systematically, statewide. A good example is the evaluation of concrete sealers. RIDOT research has resulted in the use of effective concrete sealers on bridge elements throughout the State to improve bridge durability. RIDOT has derived a test procedure to evaluate the durability and effectiveness of sealers in freeze/thaw conditions.

Implementation of 'Metalizing' and weathering steels to improve the durability and reduce maintenance of steel structures – The Department has used thermal and flame sprayed metalizing and galvanizing for steel girders. Weathering steels for bridge superstructures and has also used. A recently constructed arch bridge was shop-metalized and painted with excellent results.

Routine Use of MSE and Modular Block Retaining Walls – RIDOT commonly utilizes Mechanically Stabilized Earth and Modular Block retaining wall systems throughout their highway network, successfully implementing wall technologies that greatly reduce initial and life-cycle costs over conventional cast-in-place retaining walls. Extensible (plastic) reinforcements are commonly used to construct MSE and modular block walls.

Successful Implementation of Value Engineering on Major Bridge Projects – Although RIDOT does not have a formal policy for the implementation of value engineering, on several bridge projects, particularly major bridge projects

Other Research Efforts – RIDOT is currently is health monitoring systems and steel bridge paint systems. Geofoams have been successfully employed as lightweight embankment.

Effective Program for Bridge Preventive Maintenance – RIDOT has developed a cost-effective bridge preventive maintenance strategy to extend the life of existing bridges and reduce maintenance and rehabilitation costs. This consists of deck and superstructure "washing". This strategy is preformed systematically and statewide. Construction Specifications 820.0200 and 820.0300 provide instruction for High-Pressure Water Cleaning of Concrete Surfaces and Bridge Structures, respectively.

Accurate Estimates of Bid prices on Construction Projects - RIDOT has been able to maintain estimates of bridge and highway projects within 5% of actual bid costs. This is an exceptional result and the means for this lies partly within their process for emphasizing the review of constructability during the scoping, development and design phases of projects. No data was collected relating to final construction cost verses original bid cost.

IV. REVIEW OF RIDOT'S STRUCTURAL ENGINEERING PROGRAM

A. ORGANIZATION

There are approximately 750 highway bridges in the Rhode Island National Bridge Inventory. RIDOT owns approximately 600 bridges, including 3 toll bridges. Structural design in RIDOT is centralized and managed within one central office under the Bridge Design office. There are no district design offices in Rhode Island. The design staff located in the Providence office is responsible for developing and maintaining all program guidelines, manuals, policies, standards, and design aids and responsible for the design of highway bridges and walls. Currently, however, most of the Bridge Design office staff serve as project managers whose primary function is to meet routinely with consultant engineers and serve in project oversight and advisory roles. Over the past few years, the responsibility of the bridge engineering staff to develop and design projects and develop and maintain process guidelines and policies has significantly diminished. A great deal of time is devoted to implementing and maintaining a new project tracking system. The design staff does not have up-to-date design or analysis tools to apply LRFD Design Specifications. The design staff does no design work in-house, that is, 100% of bridge and wall design projects are completed by consultant engineers. The role of generating and maintaining engineering policies and guidelines within the bridge engineering office requiring technical knowledge has also recently been outsourced to consultants, as well. The bridge design staff does not have a formal quality assurance program in place. Rather, general plan reviews rather than detailed technical reviews are conducted, ad-hoc. A general PSE Checklist is used to track whether the PSE package is complete with appropriate environmental, contractual and right of way documentation has been provided, rather than a bridge design quality checklist.

The Bridge Design office is comprised of five, 2 to 3 person teams who report to a bridge program manager. The Bridge Program Manager also directs a bridge management and inspection staff. The bridge management and inspection staff role has greatly been diminished in recent years as all bridge inspections are now performed by consultants. The RIDOT Bridge Design office does not have a business plan that details specific roles and goals or objectives. The total bridge design engineer staff positions are summarized in Table 1.

SPECIALTY	NO. OF PERSONNEL
Management	3
Structural design	0
Consultant review	14
Load rating	2
Technicians/Drafting	0
Research	1
Bridge Mngt./Insp.	5
Major bridge design	0
Geotechnical design	0
Hydraulic design	0

Table 1: Structures Design Offices: Engineering staff levels.

A summary of the approximate number of new bridges designed each year by RIDOT bridge design office and rehabilitations is summarized in Table 2.

	BRIDGE DESIGNS
Structural Design Office – new bridges	0
Structural Design Office - rehabilitations	0
New Consultant Designs reviewed	6-8
Rehabilitation Projects reviewed	6-8

Table 2: Approximate number of new bridge designs and rehabilitations per year

B. STRUCTURAL UNIT OVERVIEW

Structures Office

The primary roles and responsibilities of the Bridge Design office include establishing statewide bridge design management and inspection policies and procedures, conducting 10%, 30% and 90% reviews of design plans, performing load ratings for routine bridges (large span bridge load ratings are performed by consultants that maintain the necessary software), following up on design issues during the construction process, attending public hearings and pre-construction meetings, and overseeing the bridge management and inspection program. The Bridge Office is also responsible for reviews of shop drawings and falsework. However, the technical review of these items is limited since technical expertise is diminishing and the design office lacks analysis software to perform detailed reviews.

The roles of the staff have been scaled back dramatically over the past several years as the Department continues to outsource all design work, development of the bridge design guidelines, all bridge inspections, and more and more project development responsibility. Staff engineers often indicated a decline in their ability to interpret and apply continuously evolving design standards and indicate they have access to few if any up-to-date analytical tools to assess the adequacy of structural element designs. Some design training seminars are provided, however the staff does not have an opportunity to apply the design and analysis training they receive. According to the staff engineers, this has led to the loss of technical expertise among design specialists. The design staff selectively performs cursory checks of the design of structural components on design projects, however, these checks are not formally monitored or programmed and the detail which the checks are made are based upon the specialists experience level.

Structures Research Program

The RIDOT Research program operates on a budget of approximately $300 million annually, of which a share is directed to applied research in bridge, wall and foundation technologies. The RIDOT research program has been effective in establishing value added procedures to implement technological advances statewide, including:

- High-performance concrete for bridge super- and substructures
- High performance steel bridge paint systems, galvanizing and metalizing
- Modular Block and Mechanically Stabilized Earth Retaining Structures

- Geofoam embankments
- Structural system health monitoring applications
- Concrete curing techniques and concrete additives to minimize drying shrinkage

One research engineer works independently, but in close cooperation with the Bridge Design Office to direct research funds to analyze the benefits of new products and technologies. The RIDOT Materials laboratory staff includes 3 engineers and 3 technicians. The total research program funding level provides for approximately 5 projects a year. Half of those projects are completed in-house. The projects that are funded are selected by a panel of RIDOT Managers across all disciplines.

There are no district offices in Rhode Island. All of the bridge design and inspection functions are centralized in the bridge design office. The Bridge Design Office coordinates with the field office staff during construction and the Bridge Design staff does support on-call requests from the construction or project offices as they arise. The design staff serves as project managers and will help construction personnel address design issues and plan inconsistencies.

C. OVERVIEW OF QUESTIONNAIRE – STRUCTURAL DESIGN PROGRAM PROCEDURES AND PRACTICES

Design Procedures
Several RIDOT manuals, standards, directives, and guidelines are used to maintain uniformity in design and detailing. The manuals are available in electronic format from the RIDOT website. The primary guidelines are a recently drafted Bridge Design Manual (2006 LRFD guidance), To All Consultant (TAC) Memorandums, Design Policy Memorandums (DPMs) and Bridge Standard Details. Most of these documents and guidelines have been updated since 2004.

Approximately 30% of new bridge designs are currently being designed in accordance the LRFD Specifications, and the State intends to meet the target date to have all new bridges designed in accordance with the LRFD Specifications by October 1, 2007. A formal implementation plan is not used to direct LRFD implementation. Although the Bridge Design office does not provide routine and formal training for in-house and consultant engineers, the consultants that are selected for LRFD projects have design experience as a result of working on projects in LRFD in adjacent States.

General RIDOT Structures Design office policies and practices are summarized:

- Maintainability: Although no specific guidelines are provided by RIDOT, Section 2 of the RIDOT BDM requires the Managing Bridge Engineer to be notified when elements are included in a design that will require the bridge to be closed to traffic for maintenance. Provisions for jacking bridges shall be incorporated into all bridge designs. For complex structures such as moveable bridges and long span bridges, the RIDOT requires the consultant to provide a bridge-specific Inspection and Maintenance Manual. Environmental exposure criteria are not specified.

- Constructability: The Bridge Design office engineers focus a considerable amount of effort on reviewing project plans for 'constructability'. The project manager conducts 'constructability' assessments of design plans at the 10%, 30% and 90% complete stage of each bridge project. However, these assessments appear to be primarily focused on proactively reducing the potential for construction delays and claims. Based on our interviews with project managers, it is unlikely that the bridge design staff is capable of performing strength limit state constructability analyses of I-girders. The RIDOT BDM does not include specific criteria to ensure that consultants are performing necessary analytical checks to ensure adequate emphasis is placed on the stability of girders under construction loads. A simple precautionary statement is required on plans and shop drawings in Section 6 of the BDM. On complex projects, the Department has used independent consultants to perform a constructability study. We recommend that RIDOT strengthen their guidelines on constructability for all projects, especially those that incorporate steel I-girders, in accordance with criteria in the AASHTO LRFD Specifications, article 6.10.3 and the AASHTO/NSBA Publication GDS 12.1-2003 – Design for Constructability.

- Aesthetics: No formal bridge-specific policies. However, TAC-0006 issues DPM 410.04 – Context Sensitive Solutions (CSS), which provides for the goal of the Department's CSS policy to be applied on all RIDOT projects.

- Alternate designs: No formal policy. On bridge design projects that exceed $10M, RIDOT evaluates the need for an alternate design in cooperation with the FHWA Division office. Alternate designs have been used on at least 2 occasions.

- Value engineering: No formal policy. RIDOT has a value engineering construction specification that is added to the contract based on the Deputy Chief Engineers determination at the 90% complete review meeting.

- Contractor design alternates: No formal policy. These alternates have been permitted as part of the value engineering specification on recent projects.

- Incentive/disincentive clauses: No formal policy. RIDOT has a value engineering construction specification that is added to the contract based on the Deputy Chief Engineers determination at the 90% complete review meeting.

- Design/build: Not used in Rhode Island.

- Accelerated Construction / Use of prefabricated elements: RIDOT has implemented the FHWA ACTT program on one major corridor project and found the effort to provide several cost efficiencies.

Specific RIDOT guidelines for the analysis and design of bridges and foundations for scour are very limited. The current design criteria defined in the BDM does not reference FHWA Hydraulic Engineering Circular 18 entitled "Evaluating Scour at Bridges" or specific procedures that provide sufficient guidance to ensure that consultants perform scour analyses consistently. At the time of this review, RIDOT did not have a hydraulics specialist on staff. It could not be established that the RIDOT has a staff engineer who could perform site-specific scour analyses. The PS&E checklist does not include the need for the RIDOT project manager to make an assessment of the scour computations for each bridge project.

Likewise, specific RIDOT guidelines and criteria for the design and analysis of geotechnical features such as pile foundations, spread footings and retaining walls exist only in a very simple and general form in the BDM. No current RIDOT staff engineer is assigned the responsibility to be a specialist in the design of foundations and walls. The Bridge office is aware of this technical expertise deficiency and is contemplating hiring at least one full-time geotechnical specialist. We are not aware of any State in the nation that does not have at least one full-time geotechnical and hydraulic specialist to manage the design and analysis policies and procedures for geotechnical/foundation and hydraulic features design.

The Bridge Design office is out-sourcing the development and maintenance of standard bridge details more frequently. The Bridge Design office staff prepares and review updates to structural items in the State's Standard Construction Specifications. Although one person reviews standard construction specifications and special provisions for structures items, any bridge designer can initiate a new specification or change in an existing specification.

Design – General

Table 3 illustrates the typical bridge structures used statewide and the relative frequency of use. RIDOT staff does not currently produce or maintain standard plans for items such as AASHTO, box and Double-Tee prestressed concrete beams or steel beams.

Structure Type	Frequency	Structure Type	Frequency	Structure Type	Frequency
RC Slabs	1	PSC Box beams	4	Steel I-girders	4
RC T-beam	1	PSC Double Tee	1	Steel Rolled beams	3
PSC Bulb Tees	4	PSC Slabs	2	Concrete Segmental	1
PSC I-beams	1	Steel box	2	Other:	

Table 3: Frequency of use of superstructure elements: Ranked 1 (rarely) to 5 (often).

Corrosion protection measures are used for superstructures and substructures. On a project-by-project basis, weathering steel is used. The Bridge Design office has coordinated with the Research office to utilize thermal-sprayed zinc coatings on several projects. Use of epoxy coated reinforcing steel is standard practice as is the use high performance, low permeability deck and substructure concrete.

RIDOT has recently incorporated high performance materials into the structural network and HPC is used on virtually all projects, statewide.

High Performance Concrete: Principally, the goal of the Department's HPC implementation has been the focus of reducing chloride ion intrusion, or reducing the permeability of concrete rather than the need to increase concrete strength. The target is to provide concrete with a threshold permeability of 2000 coulombs or less. HPC is used in all decks and most substructures.

High Performance Steel: High Performance structural steel has not yet been fully utilized, although the RIDOT is interested in identifying suitable projects for implementation.

Fiber Reinforced Polymers: Not used to date. Research costs may be prohibitive for the expected cost benefit.

The RIDOT routinely utilizes epoxy-coated steel and is currently assessing the effectiveness of a proprietary product "Z-bar". Cathodic protection systems are not used by the Department.

Approximately 30% of bridge projects are currently being designed in accordance with the AASHTO LRFD Specifications and the remaining 70% of the projects are being designed in accordance with the AASHTO Standard Specifications. The HL-93 live load is used with the LRFD design criteria while a HS25 live load has been customarily used with the Standard Specifications. The RIDOT BDM suggests that the AASHTO Pedestrian Bridge Guide Specification loadings are to be used in the design of bridges with only pedestrian and/or bicycle traffic.

The Bridge Design office makes very limited use of design software and does not have up-to-date software that can be used to analyze all of the common bridge superstructures or foundations that they are responsible for overseeing. Older versions of PCBridge are available, as are load rating analysis tools (LFD) utilized by the bridge management/inspection staff.

Bridge expansion joints are avoided when possible. When utilized, joints selections include fixed joints for up to 3/8 inch anticipated movement, strip seals for up to 5 inches of movement, and modular joints for up to 28 inches of movement. The contract drawings require the design engineer to provide a table with the joint opening for installation temperatures of 15, 30, 45, 60, 75 and 90 degrees. The BDM specifically describes which procedures are to be used to calculate the range of movement. Procedure B in the LRFD Specifications is called for when steel and concrete I-girder bridge superstructures are used and Procedure A is required for all other bridge superstructures.

Approach slabs are used for all bridges regardless of pavement type. RIDOT is experimenting with using flowable fill behind the backwall to eliminate approach slab settlement. Within the new BDM, sleeper slabs are specified whenever integral abutments are utilized.

RIDOT encourages the use of integral and semi-integral abutments, whenever possible. Use of integral abutments are not to be used when the following conditions exist: bridge skews greater than 30 degrees; steel and concrete bridges having total length of 350 and 600 feet, respectively; grade differential of more than 5% between abutments; only for horizontal bridge alignments; girder depths greater than 6 feet. Integral abutments are used only with steel and concrete I-beam and box beam bridges.

Both stay-in-place (SIP) steel and PSC deck forms are utilized on a project-by-project basis by the Department. On at least one recent project the contractor was permitted to use either type of form.

The Department's current seismic design criteria is based on a force-based "two level" design principle and is applied to all bridges. The objective is that during the expected earthquake (a 500 year event) a critical structure (i.e., provides a link to critical facilities) must sustain no damage and provide full access to traffic. A non-critical bridge may sustain minimal damage but must be repairable under traffic after the event. During the rare earthquake (a 2475 year ground motion return period) a non-critical structure must not collapse and a critical structure must provide access for emergency vehicles and be repairable within a short time after the event.

Additionally, where damage is permitted, for all structures the damage must be detectable and repairable. This is consistent with the guidelines presented in NCHRP 12-49. Probabilistic ground motions developed for the upper-level earthquake ground motion by the USGS (referred to as the maximum Credible Earthquake in NCHRP 12-49) were calculated for a probability of exceedance of 2% in 50 years, and are used. They are nearly identical to the 2475 year ground motion return period.

In addition to the two-level approach, the seismic provisions specified by RIDOT incorporate the soil site classes as proposed by NCHRP 12-49. The RIDOT provisions incorporate the use of spectral accelerations. The construction of the "two-point" method procedure outlined in NCHRP 12-49 with a response spectral acceleration at the short period(0.2 seconds) and at the 1 second period is used. Vertical accelerations are not considered by RIDOT and are thought to have an insignificant impact based on sample analyses. RIDOT bridge design staff does not have the expertise to conduct seismic analyses and consultants are required to perform this work. The PSE checklist does not require the RIDOT project manager to assess seismic design computations.

Likewise, for the extreme event limit state vessel collision analysis, RIDOT calls for consultants to follow AASHTO provisions, but in-house staff does not have the expertise to review the design computations. A Navigation Study is performed to determine whether a bridge should be designed for vessel collision.

Computer assisted drafting techniques are used for plan preparation by consultants. RIDOT does not maintain up-to-date CADD software in-house. Consultants often use standardized details in plan preparation. Standard plans are not maintained by RIDOT.

The current practice for deck drainage depends on the bridge location and length and is provided in the BDM. Whenever possible, the Department calls for deck drainage to be carried off the bridge to approach drainage structures. FHWA HEC 21 is referred to for the design of bridge deck drainage. Sag vertical curves are avoided in deck profiles and minimum cross slopes of ¼ inch per foot are specified. Bridges scuppers with free fall drop pipes are utilized when drainage can effectively be dropped to avoid traffic, pavement, sidewalks, embankments and private property. Eight inch diameter downspouts are required.

Most new traffic railings for RIDOT structures meet Test Level 4 or 5 in NCHRP Report 350. TL-2 and TL-3 rails can be used in the following instances: where ADT is less than 500; where ADTT is less than 5%, where design speeds are less than 40 mph. Test Level 5 is used for all interstate highway bridges. TL-5 railings are also considered for non-Interstate bridges with high-volume, high-speed roadways.

Commonly used bearings are elastomeric bearing pads (both plain and steel reinforced), disc, pot bearings, and standard steel sliding bearings. Standard sheets are available for all bearings and most recently developed by consultants.

The commonly used types of bridge piers are hammerhead, wall, cap and column, pile trestle and post-tensioned bents. The BDM provides simple and commonly specified instruction for applying live load vertical reactions and longitudinal and transverse horizontal loads.

The deck design methodology commonly used is the traditional design approach utilizing the tabularized live load moments provided in the LRFD Specification appendix. On a project-by-project basis, the empirical methods of deck design can be approved. Refined analyses are rarely used except on unique and heavily skewed bridges.

Structural Steel Design

The types of structural steel used in Rhode Island are Grade 36 (rarely used today) and Grade 50. RIDOT has not used HPS extensively, to date. Weathering steels (Grade 50W) are often specified with the following general limitations: minimize the number of expansion joints (no field splicing of the expansion joint material allowed); structural steel within 5 feet of an expansion joint is to be painted; the number of scuppers is minimized; and only mechanical fasteners suitable for unpainted weathering steel are permitted. Unpainted weathering steel is not permitted in marine environments (i.e., bridges located within 5 miles of the coastline), close to industrial facilities capable of producing emissions of contaminated material, in areas subjected to prolonged wetting, or on low clearance structures with less than 24 feet vertical clearance to the roadway below.

A summary of current practices for structural steel design follows.

- Use of fracture critical designs for superstructures or substructures: Fracture Critical members are discouraged. When included, must be approved by the Managing Bridge Engineer and clearly noted on the plans.

- Fatigue prone details (i.e., category D, E and E') are discouraged. When included, must be approved by the Managing Bridge Engineer and clearly noted on the plans.

- Composite design: All bridges designed fully composite in both positive and negative moment areas.

- Continuity: All bridge decks and deck supporting members are made continuous.

- Girder spacing (minimum-maximum): The practice is to try to optimize girder spacing.

- Transverse stiffeners: Transverse stiffeners are placed on both sides of the web except for fascia girders. The AASHTO/NSBA Collaboration Publication G12.1 -2003 is referenced. The RIDOT goal is to design with a reasonable (cost optimal) number of transverse stiffeners.

- Longitudinal stiffeners are discouraged. RIDOT prefers to use a thicker web plate to eliminate need. Longitudinal stiffeners are used within box girders and at haunched locations on long span structures.

- Haunches: Haunches are used only when economically justified on bridges with spans over 400 feet.

- Flange transitions (thickness and width): RIDOT practice is to encourage keeping the flanges a constant width and vary their thickness as required for loads. Plate thickness is not reduced by more than 50 percent at a splice. Goal is to maximize flange width to thickness ratio within the limits provided by the LRFD Specification.

- Bottom lateral bracing: Used rarely and only if required per analysis.

- Connector plates: In accordance with the LRFD Specifications positive connection to top and bottom flange.

- Structural bolting (methods allowed/used) in bridge structures: Guidance is not provided.

Prestressed Concrete Design

The RIDOT currently uses New England bulb tees, adjacent and spread box beam designs with wearing surface and full-depth deck, respectively, SIP forms and prestressed piles. The prestressing strand used is Grade 270, low relaxation seven wire strand meeting ASTM A-416. Strand diameters of 0.5 and 0.6-inch are commonly used and 0.375-inch strand are used for SIPs. Only debonded strands are used and must be debonded with plastic sheathing taped to the strand. The Department requires that the level of debonding within that permitted by the AASHTO Specifications. A summary of current practices for prestressed concrete design follows.

- Compressive strength typically specified: 6000 psi
- Maximum used: 7000 psi
- Release strength: Attempt to target lowest possible, but typically 4000 to 4200 psi for 6000 psi concrete.
- Maximum used: High transfer strength is permitted when approved by the Managing Bridge Engineer and when the producer's daily casting cycle is not interrupted.
- Allowable tension in the precompressed tensile zone at service load: Specified at Service Limit State before and after losses; 0.12 f_{ci}'' and 0.0948 f_c', respectively. No tension is allowed in the precompressed tensile zone in components that are subject to severe corrosion conditions (i.e., within 5 miles of the coast line or bridges with vertical clearances less than 24 feet.
- Shear reinforcement for vertical shear: RIDOT specifies the LRFD sectional design approach.
- Shear reinforcement for horizontal shear: Follow the AASHTO specifications.
- I-beams made continuous for live load: Multi-span bridges are designed as continuous for loads placed on the bridge after the continuity diaphrams and concrete deck has cured. Girders must be cast 90 days in advance of casting the diaphram and are designed in accordance with AASHTO at the Service Limit State.
- Spliced girders: Have been used for one project and will be considered for use with longer span New England bulb tees.
- Haunched girders: No policy and not used to date.
- Prestressed concrete deck panels (not SIP forms): Standard details are available for deck panels and they are allowed by RIDOT.
- Types of bearing devices: Reinforced elastomeric bearing pads are used almost exclusively with precast beams.

Use of Consultants
As stated previously, consultants design all bridge projects in Rhode Island. Consultant forces are responsible for preparing special provisions for bridge projects and are relied on to develop standard details, and even to draft Department design guidelines and policies. The Managing Bridge Engineer and staff review and approve all special provisions. Consultants are increasingly being used to perform construction engineering, as well.

RIDOT does not pre-qualify consultants and therefore goes through a formal selection process for each bridge project that is awarded. RIDOT staff suggested that a considerable amount of time and resource demand could be saved if the Department used a prequalification process for consultant selection.

RIDOT has Design Policy Memos that document the Advertising Process (DPM 460.09), and a comprehensive Plan Content Requirements (450.02). DPM 230.05, Monthly Progress Reports for Consultant Contract Monitoring, provides guidance for consultants for preparing monthly progress reports. The Department is currently implementing a new project tracking system. Bridge Design office staff unanimously confirmed that the agencies adoption of these new tracking processes and systems continue to place the engineering staff in an administrative role, while their responsibility for oversight and ability to apply design standards continue to diminish.

Research and Technology Development and Experimental Studies
In the last five years, the following structural related research, development, and experimental studies have been conducted or sponsored by the RIDOT :

- Prestressed pile embedment into footing caps, and also pile splices
- Fiber Reinforced Polymer repairs
- Ship/Barge Impact - Statewide Analyses of traffic and vessel forces validation
- Prestressing strand development length studies
- Stainless steel clad rebar and MMFX rebar
- Fiber Reinforced Polymer concrete filled pile shells and bent caps
- Structural investigations of ICP piles.

Training
While RIDOT occasionally hosts technical training courses for in-house design staff and consultant engineers, the training has been infrequent and not sufficient to provide in-house technical staff with a complete level of understanding of the LRFD Specifications. Furthermore, the staff has indicated that training seminars are typically not followed up with the opportunity to apply the training material. A comprehensive selection of current software for the design and analysis of the most commonly used structural elements is not maintained by the Department. Therefore, RIDOT project managers do not maintain knowledge of the fundamental concepts of structural design and analysis, nor do they have a rigorous process to investigate the quality of consultant designs or the capability to analyze common structural elements. Although no specific training was formally requested, the design staff indicated a need for continuous levels of technical design training. They also need up-to-date design tools, such as analysis software, and time to learn how to apply the design standards to improve their level of understanding of the design specifications. Specialists can typically maintain levels of expertise much easier than those that have to re-learn basic analysis methods. As is the case in virtually every SHA, it is prudent for the Bridge Design office to ensure that a sample of projects are developed and designed in-house. Optimally, States are able to maintain levels of expertise by commonly applying analytical techniques when conducting regularly scheduled and detailed process

reviews for key bridge design components, such as superstructure, pier, foundation, wall, seismic and scour design.