REQUIREMENTS

FOR

QCONBRIDGE II
A MEMBER OF THE ALTERNATE ROUTE PROJECT

VERSION 1.0

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REVISION CHART

Version	Primary Author(s)	Description of Version	Date Completed
1.0 - Draft 1	RAB, RDP	Initial draft created for distribution and review comments	4/6/2000
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1.0	RAB, RDP	Routed for final comments. Sign off	6/14/2000

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1. INTRODUCTION

1.1 Project Overview

Bridge engineering and software engineering are dynamic disciplines. Over the past ten years there have been dramatic changes in both fields. As a result, our software has become out of date with modern operating systems and computing standards, our bridge design codes have changed, and simplifications to ease longhand design efforts are no longer necessary.

Although relatively new, the WSDOT LRFD live load analysis program, QConBridge, is a victim of these ongoing changes. The original QConBridge was developed using the Borland Object Windows Library (OWL) framework. Borland/Inprise has dropped OWL from their product line and its long-term support is in question. We feel that it is prudent to re-implement the program using the Microsoft Foundation Classes (MFC) and Microsoft's Active Template Library (ATL), in order to avoid technology obsolescence.

When QConBridge was originally developed, WSDOT was beginning its transition to the LRFD Specifications. The focus was on superstructure designs. As WSDOT's LRFD design capabilities have matured, we find that we have outgrown the capabilities of QConBridge. The LRFD Specifications and WSDOT design practice have also changed since development of the original QConBridge. To address these issues, the QConBridge program will be upgraded. For the sake of brevity, this upgraded version of the program will be called QConBridge II.

The goal of this project is to deliver an LRFD-based superstructure analysis tool to the desktops of WSDOT bridge engineers. The driving factors for this project are new expectations from bridge engineers regarding the quality and functionality of bridge engineering software, a move to component-based software systems, and to keep up with the ever-changing LRFD bridge design specifications.

1.2 Document Organization

This document is divided into five sections, Introduction, System Overview, Functional Requirements, Documentation Requirements, and Deployment Requirements. The Introduction section describes the purpose and background of the QConBridge II project. The System Overview section provides a high level view of the QConBridge II application. The Functional Requirements section provides detailed functional and operational requirements for the software. The Documentation Requirements section provides information for the documentation that must be delivered with the QConBridge II project. The Deployment Requirements section specifies how and to whom QConBridge II must be deployed.

1.3 Reference Materials

1. AASHTO LRFD Bridge Design Specifications, US and SI Units, First Edition, 1994
2. AASHTO LRFD Bridge Design Specifications, US and SI Units, First Edition, 1994 with 1996 Interim Provisions
3. AASHTO LRFD Bridge Design Specifications, US and SI Units, Second Edition, 1998

4. AASHTO LRFD Bridge Design Specifications, US and SI Units, Second Edition, 1998 with 1999 Interim Provisions
5. Bridge Design Manual, Washington State Department of Transportation

2. SYSTEM OVERVIEW

2.1 System Concept

This section describes the overall system concept, target users and computing environment, and provides a high level view of the QConBridge II computer program.

2.1.1 *Bridge-centric* Software

This program will provide a *Bridge-centric* approach to the user interface. Traditional bridge engineering software forces the engineer to focus his/her attention on cryptic data file formats[1] or verbose problem oriented languages[2], batch processing, and third party text editors. Some bridge software vendors provide a dialog-based Windows® user interface, but the focus of the interface is to construct a cryptic data file and not to model a bridge[3].

The *Bridge-centric* approach employs principles of visualization and direct manipulation, resulting in software that enables engineers to concentrate on modeling a bridge and studying its behavior. Examples of *Bridge-centric* software are WSDOT's QConBridge and PGSuper programs.

2.1.2 *Software in the loop*

The *Software in the loop* concept is new to bridge engineering. This concept is complementary to the *Engineer in the loop* concept used by AASHTO for its large-scale engineering software. Software built around the *Engineer in the loop* idea encapsulates the entire analysis and design process in a closed loop, and then provides the engineer access to the loop at discrete locations. The *Software in the loop* concept recognizes the engineer as the owner of the analysis and design process and further recognizes that computer software is merely a tool used to automate routine tasks.

By adding the software to the loop, the program complements and enhances the way in which an engineer works. Well-designed *software in the loop* programs help to automate mundane, day-to-day tasks performed by engineers. This helps to free the engineer to do what he does best – make high-level, engineering decisions.

[1] All of the WSDOT bridge programs created before 1996 use some sort of cryptic data file format.

[2] A classic example of verbose POL is the old STRUDL programs.

[3] The latest version of Merlin-Dash and LPile + provide dialog based interfaces whose goal is to build a data file for a batch processor.

2.2 Operational Environment

2.2.1 Hardware

The minimum target hardware platform for this program is:

- IBM-compatible personal computer with Pentium II - 100 MHz processor or better
- SVGA graphics (800x600 resolution, or higher)
- 16 MB of RAM
- Internal hard drive with at least 10 MB of free space
- CDROM drive and/or Internet connection

2.2.2 Operating System

The target operating system for this program is Windows NT 4.0 - Service Pack 4, or later.

2.2.3 Peripherals

The target computer for this program should be equipped with either a black and white or a color printer.

2.2.4 Other Software

The target computer will have Microsoft™ Internet Explorer Version 5.0 or later. (PGSuper made very effective use of IE and it is anticipated that it will be used again in QConBridge)

2.3 User Characteristics

This section describes the anticipated users of QConBridge II. The targeted users of QConBridge II are WSDOT Bridge Design Engineers and WSDOT consulting engineers. This software will also be made available to the international bridge engineering community via the Internet.

2.3.1 Basic Skills

The user of QConBridge II should be computer literate, familiar with the Windows™ family of operating systems, a competent structural engineer, and should be able to:

- Operate a mouse
- Accomplish keyboard input
- Understand basic concepts of bridge engineering, and structural analysis
- Understand the LRFD Bridge Design Specification

2.3.2 Targeted Roles

It is expected that a typical user will fall into one or more of the following roles.

2.3.2.1 Designer

Performs detailed design of structural elements to satisfy strength, durability, and constructability code requirements. Computes structural quantities. Creates engineering drawings and specifications.

2.3.2.2 Preliminary Designer

Performs preliminary design of roadway and overall bridge structure. Determines bridge type, pier placement, member sizes and member spacing. Requires quick feedback of preliminary structural forces and displacements.

2.3.2.3 Design Checker

Evaluates a design against a given set of criteria. Checks for strength, serviceability, constructability and compliance with code requirements.

2.3.2.4 Administrator

Configures the program to describe bridge configurations, modify code provisions, set defaults, and sets options according to agency policy. Maintains office-wide default settings.

2.3.3 Roles Not Considered

The needs of a user performing the following roles are not considered:

- Bridge Technical Advisor
- Construction/Manufacturing Engineer

2.4 External Interfaces

QConBridge II must interface with the Internet, enabling users access to up to date information. It is envisioned that external programs might interface with QConBridge, see the System Architecture documentation for details.

2.5 Functional Requirements Overview

This section provides a high level description of the major requirements for QConBridge II.

QConBridge II will be limited to analyzing single and multiple span bridge structures that satisfy the provisions of LRFD Article 4.6.2 *Approximate Methods of Analysis*. The program must be capable of determining structural responses to dead loads, differential support settlement, uniform temperature changes, vehicular live loads, and pedestrian live loads in the superstructure and the substructure. Analysis must be performed in accordance with the provisions of the AASHTO LRFD Bridge Design Specification 2nd Edition, 1998, with 1999 interim provisions and the WSDOT Bridge Design Manual.

3. FUNCTIONAL REQUIREMENTS

The requirements described in this section define the required functionality of QConBridge II. That is, this section describes the engineering problem the program must solve.

3.1 Governing Specifications

QConBridge II will perform its analytical computations in accordance with the following specifications

- AASHTO LRFD Bridge Design Specification, 2nd Edition, with 1999 revisions.
- WSDOT Bridge Design Manual (BDM)

The user must be able to base calculations on either the US or SI versions of the LRFD specifications.

The user must be able to choose to use LRFD or BDM specifications.

3.2 Bridge Modeling

The subsections that follow describe the types and attributes of bridges that QConBridge II must be capable of modeling.

3.2.1 Bridge Types

3.2.1.1 Superstructure Modeling

QConBridge II shall model Precast Girder Structures with Cast-In-Place concrete decks, Built-up Steel Plate Girders with Cast-In-Place concrete decks, and Rolled Steel Beams with Cover Plates with Cast-In-Place concrete desks. QConBridge II shall also model an idealized bridge structure that is described by its span lengths, connectivity, boundary conditions, section properties, and material properties.

3.2.1.2 Substructure Modeling

QConBridge II shall model abutments and interior piers. These substructure elements can be modeled as reinforced concrete frames or idealized structures. QConBridge II shall model piers with round, rectangular, and rounded-rectangular cross sections. The round and rectangular columns can have linear tapers over the height of the column. Crossbeams will be rectangular in section, but can have a linear taper in elevation.

3.2.2 Bridge Attributes

3.2.2.1 Number of Spans

QConBridge II shall model single and multiple span bridges. The maximum number of spans will be limited only by the user's computer.

3.2.2.2 Hinges and End Span Continuity

QConBridge II shall allow for the modeling of in-span hinges and the presence or lack of moment continuity with adjacent spans and support elements. Spans can have 0, 1, or 2 in-span hinges. Either end of a span can have or not have moment continuity with its adjacent span or support elements. QConBridge II must restrict the modeling of in-span hinges and end span continuity to those combinations that represent a statically stable structure.

3.2.2.3 Geometry

QConBridge II shall account for effects of horizontal curvature and skewed supports, but is restricted to only those bridge types that satisfy the requirements of LRFD 4.6.2.2 (Curvature in plan is less than the limit specified in 4.6.1.2, skew angle between two adjacent lines of support does not exceed 10°).

QConBridge II shall account for vertical curve effects when computing dead loads and possibly column heights, but not when creating structural analysis models. That is, elements of analytical models that represent the superstructure will be horizontal.

3.2.2.4 Cross Sections

QConBridge II shall accommodate non-prismatic cross sections by modeling a series of prismatic segments. Section properties will not be interpolated between cross section definitions.

3.2.2.5 External Boundary Conditions

QConBridge II shall model boundary conditions as pinned, roller, or fixed support. QConBridge II will not model elastic supports. To maintain compatibility of QConBridge Version 1, the exterior ends of the first and last span can be cantilevers.

3.2.2.6 Stages

QConBridge II shall model the various stages of construction for the bridge types it supports. For the idealized bridge model, the user can create as many stages necessary to model the structure. Analysis results from one stage to the next are assumed to be cumulative (that is, the total result after stage n is equal to the sum of the responses from stage 1, 2, … n-2, and n-1. It is assumed that the law of superposition is applicable).

Section properties, material properties, boundary conditions, and loading may be changed at each stage. The total number of spans and the length of each span must be constant in all stages.

Substructure elements will be modeled in all stages. The properties of substructure elements will be constant in all stages.

3.2.2.7 Staged Model of Precast Girder Structures

Precast girder structures shall be modeled with three stages. The first stage will consist of a series of simply supported non-composite girders supporting the weight of the wet bridge deck. The second stage will consist of composite girders supporting the weight of superimposed dead loads including traffic barriers, median barriers, utilities, and wearing surface. The final stage is the same as the second stage, except the model is subjected to vehicular and pedestrian live loads.

Also, precast girder structures can be modeled as simple spans for positive moments and continuous spans for negative moments. The resulting envelopes of behavior will be computed.

3.2.2.8 Staged Modeling of Steel Beam or Girder Structures

Steel beam or girder structures shall be modeled with at least three stages. The first stage(s) will model the slab pour sequence. This will consist of the non-composite girder sections supporting the weight of the wet bridge deck and composite girder sections supporting the weight of previously pour deck segments. The second to last stage will consist of composite girders supporting the weight of superimposed dead loads including traffic barriers, median barriers, utilities, and wearing surface. The final stage is the same as the second stage, except the model is subjected to vehicular and pedestrian live loads.

3.3 Loads

The subsections that follow describe the various requirements for loads.

3.3.1 General

In addition to the LRFD load cases and limit state combinations, QConBridge II shall support user-defined loads, load groups, load cases, and load combinations. Figure 1 illustrates the load hierarchy that QConBridge II will support.

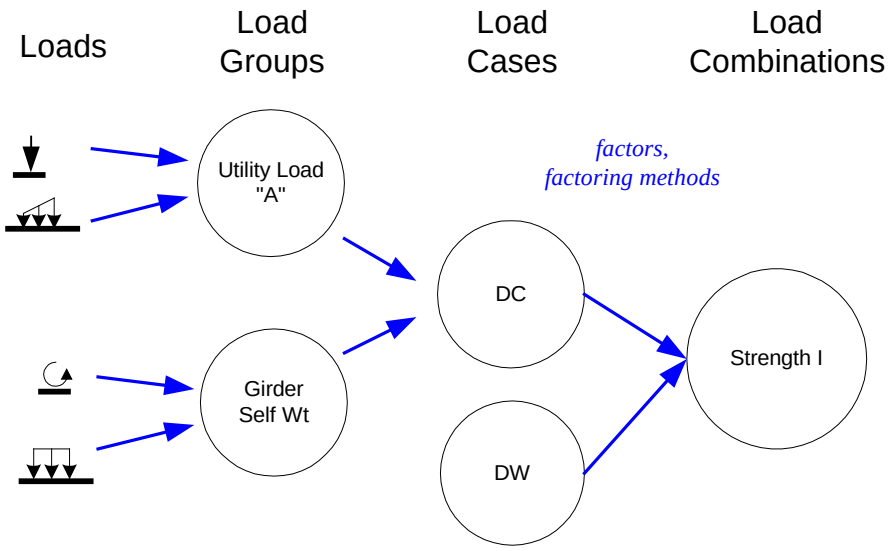

Figure 1 Load Hierarchy

3.3.1.1 Loads

At each analysis stage, the user can add externally applied loads to an analysis model. QConBridge shall support concentrated forces (vertical direction only), concentrated moments, and linearly varying distributed loads (vertical direction only). Distributed loads can be applied to a portion of a span, an entire span, or the entire bridge.

3.3.1.2 Load Group

A load group is a set of related loads such as a series of concentrated loads that represent a pipe that is supported at discrete points along the structure. Loads added to the analysis models must be associated with a load group. QConBridge shall support user defined load groups.

3.3.1.3 Load Case

A load case is a set of related load groups. The LRFD specification defines several load cases, such as DC and DW. The DC load case is a set of load groups that represents the dead load of the structure (self-weight of slab and beams, traffic barriers, appurtenances, etc.). QConBridge shall support user defined load cases.

3.3.1.4 Load Combination

A load combination is an algebraic combination of load cases. Each load case is multiplied by a scaling factor and then added to the other load cases in the combination to form a limit state response. QConBridge shall support the limit state load combinations defined in the LRFD specification, as well as user-defined load combinations.

3.3.2 Dead Load

QConBridge shall compute (at the user's option) dead loads for the structure. Dead loads shall be based on the cross sectional area and the material weight of the various bridge elements.

3.3.3 Temperature Loads

The user may optionally specify a uniform temperature rise or fall that is applied to the entire structure.

3.3.4 Differential Support Settlement

The user may optionally specify an enforced vertical displacement at any or all of the support locations. For a given multi-column bent, the enforced displacement is assumed to be the same for all columns.

3.3.5 Live Load Models

QConBridge shall support the HL93 Live Load model, including pedestrian loads and the vehicular load for live load deflection as specified in LRFD 3.6.1.3.2. QConBridge shall support the optional dual tandem plus lane load for negative moment calculations as specified in LRFD C3.6.1.3.1.

3.3.5.1 User Defined Live Load Models

QConBridge shall support user defined live load models. These models shall include, at the user's option, the simultaneous application of truck and lane loads, notional axles, dynamic load

allowance (impact factors) for above ground structural elements and footings[4], and scaling factors. Live load models shall also include "rules" that describe how the model is applied to the structure for various force effects. These “rules” shall encompass the rules used for applying all trucks described in the LRFD Specifications.

3.3.5.2 Live Load Distribution Factors

Live load shall be distributed to the interior and exterior girders of a superstructure using live load distribution factors. QConBridge shall support computation of the live load distribution factors accordance with LRFD 4.6.2.2 and the WSDOT BDM. QConBridge shall also support user defined live load distribution factors for user defined analysis models.

Live load distribution factors do not apply to substructure elements, except for reactions per girder at abutments where the distribution factor for shear shall be used.

3.4 Analysis Results

QConBridge II shall compute moments, shears, reactions, deflections, and rotations for all loads, load groups, load cases, and load combinations defined in a user's QConBridge project. QConBridge II will also compute influence lines for moments, shears, reactions, and deflections.

QConBridge II need not compute torsion in crossbeams due to unequal eccentric loads.

3.4.1 Reactions

QConBridge II shall compute reactions at abutments and piers. For abutments, QConBridge II shall compute vertical shear (axial load) and moments in the plane of the bridge. Dead load reactions will be per girder. Live load reactions will be per girder and per lane.

For piers, QConBridge II shall compute axial load, shear, and moment at the base of the idealized pier for the plane frame bridge model. QConBridge II shall also compute axial load, moment, and shear reactions normal and transverse to the plane of the pier at the base of each column.

Load combinations for above ground and buried components must be computed. In accordance with LRFD 3.6.2.1, the dynamic load allowance is not applied to substructure elements below the ground line. Spread footings, piles, and shafts are examples of these elements. As such, two sets of load combinations for reactions must be computed.

3.4.2 Envelopes and Associated Values

For any load, load group, load case, or load combination where a range of structural responses can occur, an envelope of the responses will be computed. This situation occurs when live load is present. For each extreme response, the associated structural responses will be computed. For example, for each response in the Strength I envelope for maximum moment, the corresponding Strength I shear will be computed.

[4] Per LRFD 3.6.2.1. dynamic load allowance need not be applied to foundation components that are entirely below the ground level. This means the QConBridge II will need to compute live load envelopes for superstructure and substructure elements, as well as buried substructure elements like spread footings and piles.

3.4.3 Live Load Results

QConBridge II shall be able to graphically display, and descriptively report, the live load location and configuration for extreme structural responses (i.e. maximum moment or minimum reaction). QConBridge II shall also compute corresponding structural response values throughout the structural model.

3.4.4 Location of Analysis Results

QConBridge II shall compute structural responses for moments, shears, and displacements at n^{th} points (i.e. 10^{th} points) as defined by the user. QConBridge II shall compute structural responses at all geometric and load discontinuities. Also, QConBridge II shall enable the user to specify special points of interest where analysis results are computed.

QConBridge II shall compute end of beam rotations at abutments.

For piers, QConBridge II shall compute moments and shears in the crossbeam at the face of column, centerline of column, and mid-point between columns. Axial load, transverse and longitudinal shears and moments, shall be computed at the top, bottom, and n^{th} points (i.e. 3^{rd} points) of columns.

3.5 Data Export Requirements

QConBridge II is an automated tool that accomplishes a small, but labor intensive, task in the overall design process. Engineers use the results computed by this program to perform further analysis and design.

3.5.1 Analysis Results

QConBridge II must create text-based files that contain analysis results in a tabulated format.

3.5.2 Analytical Models

QConBridge II must generate a GTSTRUDL input file that contains a 3D frame model of the bridge geometry (nodes and member connectivity) and the material and section properties of the members. QConBridge II must also generate a partial SEISAB input file that contains the description of the bridge structure.

4. DOCUMENTATION REQUIREMENTS

4.1 General Requirements

All printed documentation will be formatted for 8½" x 11" paper.

4.2 Online Help

The QConBridge II program will make extensive use of the Windows online help features. The online help shall consist of context sensitive help for every menu item and dialog control, an online user manual and an online technical reference manual. QConBridge II shall use the HTML Help system.

4.3 Tutorial

A hard-copy tutorial document will be developed that will serve as a starting point for new QConBridge II users. The document shall contain one or more tutorials that are specifically designed to demonstrate the operation of the program and to highlight its key features.

4.4 User Manual

A detailed user manual document will be developed that documents the entire QConBridge II interface, provide detailed information regarding the operation of the program and interpretation of the results generated by the program. The User Manual will be a part of the online help system.

4.5 Administrator Manual

The Administrator Manual describes how to install QConBridge II and how to configure it in a multi-user in environment. The Administrator Manual will be in hard-copy format.

4.6 Technical Reference

The technical reference manual will describe how QConBridge II works internally. It will provide the user with flowcharts and algorithms that detail how QConBridge II is doing its work. The Technical Reference will be a part of the online help system.

5. DEPLOYMENT REQUIREMENTS

5.1 Installation Program

An installation program is required for the distribution of QConBridge II. The installation program should conform to industry practice. Installation program(s) shall be customized for both WSDOT internal use and for use by the general public.

The installation program(s) shall account for the fact that the user may have a current version of QConBridge on their computer. This software shall accommodate a dual installation of QConBridge Version 1 and QConBridge Version 2, and should coexist with PGSuper and all other WSDOT software.

5.2 Distribution and Deployment

QConBridge II will be distributed to WSDOT users via the internal WSDOT network. Distribution beyond the initial product development team will occur in conjunction with product demonstrations and training. The software will be distributed to users outside of WSDOT via the Internet.

5.3 Support Services

The WSDOT Registered Users database will be updated and enhanced to handle the registration of QConBridge II users.

5.4 Product Web Site

A web site will be developed to support the QConBridge II program. This web site will contain the program information, a downloadable installation program for both the QConBridge II program and its source code, troubleshooting information, and answers to frequently asked questions.

5.4.1 Access to the Web Site from QConBridge II

QConBridge II shall contain user interface elements that allow a user to easily access the product web site.

6. SIGN OFF

I agree that this document represents our best understanding of the requirements for this project today. Future changes in this baseline can be made through the project's defined change process. I realize that approved changes might require us to renegotiate the costs, resources, and schedule commitments for this project.

	Signature	Date
Rick Brice		
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