

**State of Wisconsin/Department of Transportation**  
**RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Sep 30, 2002**

<b>Program: SPR-0010(36) FFY99</b>	<b>Part: II Research and Development</b>
<b>Project Title: Structural Analysis of Sign Bridge Structures and Luminaire Supports</b>	<b>Project ID: 0092-00-16</b>
<b>Administrative Contact:</b> Nina McLawhorn	<b>Sponsor:</b>
<b>WisDOT Technical Contact:</b> Stan Woods	<b>Approved Starting Date:</b> May 3, 2000
<b>Approved by COR/Steering Committee:</b> \$49,969.00	<b>Approved Ending Date:</b> Feb 28, 2003
<b>Project Investigator (agency &amp; contact):</b> Christopher Foley: Marquette University	

**Description:** The scope expected for the research can be broken down into two parts. With reference to luminaire supports, the research will seek to develop inspection guidelines to assess the need for replacement and/or retrofit of both high-mast and standard luminaire supports.

The research related to sign bridge structures should address the following: (a) determination of the causes of the stress cracking in the sign bridge elements; and (b) an attempt to correlate stress-crack severity and/or location to structural integrity. Specific sign bridges to be considered are included at the end of this problem statement. The results of (a) and (b) should be used to develop inspection criteria for the determination of retrofit and/or replacement of the structure. Finally, the sign bridge research should address the effect of the T-stub truss bridge support retrofit detail on future performance of the modified truss bridge.

Total Study Budget	Current FFY Budget	Expenditures for Current Quarter	Total Expenditures to Date	Percent Complete
\$49,969.00	\$16,656.34	\$0.00	\$20,001.09	85 (%)

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**Progress This Quarter:**

(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

The sign support structure research has been completed. A methodology for generating simulated turbulent wind histories using measured wind velocity records was formalized and completed. The advanced finite element models for the sign structures developed earlier on in the research were used to conduct time-history analysis of the sign support structures and make predictions regarding the expected fatigue lives of these structures subjected to naturally turbulent wind. The fatigue lives of these structures subjected to truck-induced wind gusts were also evaluated. These results are being used to develop inspection protocols for the sign support structures.

As outlined in the extension letter dated May 13, 2002 and e-mail modification dated October 8, 2002, the fatigue data used to predict the fatigue lives of the welded pipe truss sign support structures were extrapolated from data for fatigue detail categories not consistent with those actually found in these structures. As a result, the experimental study proposed in the original work plan was modified to include generation of statistical data (e.g. variation in number of stress cycles to "failure" for various stress ranges) of the common welded pipe connections found in these structures. This will make the fatigue-life predictions for these structures better. To this end, the experimental fixtures were fabricated during this quarter as well as welded steel pipe connection specimens. Two test fixtures were developed and they are shown in Figures 1 and 2.



**Figure 1: Test Fixture 1 – MTS Setup**

The motivation for the two fixtures was that the MTS machine setup (Figure 1) would allow much more rapid cycling of loading (3 – 6 Hz range) than the actuator setup and the MTS controller and machine (in general) was a more robust system capable of conducting more tests without reconditioning. The concern with the MTS fixture, however, was that the small specimen size may result in the “clamps” in the fixture influencing the larger diameter pipe wall (*e.g.* clamps may stiffen the wall) and therefore, the setup may influence the results. Test fixture 2 (Figure 2) was fabricated to simulate a condition more closely resembling the actual in-field conditions. The larger diameter pipe in this setup was cut to a length close to inflection points in the chord members of the truss. Clamps are then applied near the ends of this pipe segment to hold the specimen in place. Figure 2 illustrates (schematically) an aluminum pipe joint in the fixture. Steel specimens (fabricated by a local fabricator) will also be used in this fixture. Figure 2 illustrates the setup in a preliminary stage as load cell fixturing (for attachment to the hydraulic actuator is nearing completion). Temporary shake-down tests of the aluminum specimen shown have been run with pressure (in the hydraulic lines) control. The setup is now moving to load cell control and the remaining fixturing for this transformation will be completed very shortly.

**Figure 2: Test Fixture 2 – Larger Scale Setup.**

The high-mast luminaire finite element analysis work also progressed significantly. The simulated turbulent wind histories generated in the sign support structure work was used to conduct time-history analysis of the luminaire support structures. Fatigue life predictions of the mast-base connection, the anchor bolts, the splice connections, and handhole stiffeners are being predicted. These fatigue lives will be used to develop inspection protocols next quarter.

**Work Next Quarter:**

The next quarter will the experimental work related to the welded pipe joints carried out. Structural steel and aluminum joints will be tested the laboratory fixture (Figure 2) and structural steel specimens will be tested in the MTS fixture (Figure 1). Statistical fatigue data related to these joints will be generated for both aluminum and steel. Data will be generated for a variety of stress-range levels so that application of NCHRP 299 fatigue life prediction methodologies can be applied to the sign support structures.

The fixturing of the MTS setup (Figure 1) is complete and setup of the data acquisition system (strain gauging to evaluate bending stress levels going into the welded joint) will be completed at the time of this report’s submission. There are two items to be completed regarding the laboratory fixture (Figure 2). These are some machining related to the connection of and MTS load cell to the hydraulic actuator and setup of the data acquisition program for strain in the branch member to evaluate the magnitude of bending stresses resulting from the fixturing. Both of these issues are expected to be completed soon after submission of this report. Therefore, it is expected that fatigue testing will be underway very shortly.

The MTS and laboratory setup will allow testing to be run simultaneously in two locations and therefore, twice as much statistical data will be generated in the time frame allotted.

The fatigue life predictions and inspection protocols will also be completed this quarter.

**Circumstances affecting progress/budget:**

There are no circumstances affecting the project budget. However fatigue testing can take some time and conservative estimates for the duration of the fatigue tests were used in establishing the timeline for completion of the experimental work.

**Gantt Chart:**

The e-mail letter (dated October 8, 2002) included a modified timeline for completion of the work. Therefore, two GANTT-type charts will be shown illustrate work that has been completed to date along with the modified tasks resulting from the modification to the work plan described in the letter dated May 13, 2002.

1	Obtain Wind Velocity Data for Wisconsin from the NCDC	Completed	FY 2000 – Qtr 2
2	Generation of Wind Velocity Histograms	Completed	FY 2000 – Qtr 2/3
3	Synthesis of Truck-Induced Gust Loading Research	Completed	FY 2000 – Qtr 3
4	Assessment of Current WisDOT Inspection Procedures	70% Complete	FY 2000 – Qtr 3
5	Collect and Synthesize Luminaire Support Failure Information	Completed	FY 2000 – Qtr 3/4
6	Synthesize Past Luminaire Support Research	Completed	FY 2000 – Qtr 4
7	Develop Analytical Prediction of Luminaire Support Failures	Completed	FY 2000 – Qtr 4 / FY 2001 – Qtr 1
8	Develop Inspection Protocols for Luminaire Support Structures	80% Complete	FY 2001 – Qtr 1/2
9	Synthesis of Data Related to Cracking in Sign Support Structures	Completed	FY 2001 – Qtr 1/2
10	Field Reconnaissance of Problem Structures and Material Testing	95% Complete	FY 2001 – Qtr 1/2
11	Analytically Simulate Crack Formation in Sign Support Structures via FEA	Completed	FY 2001 – Qtr 2/4
12	Development of Inspection Protocols for Sign Support Structures	95% Complete	FY 2001 – Qtr 4 / FY 2002 – Qtr 1
13	Perform Experimental Testing		
	a. Design and Fabricate Test Fixtures	80% Complete	FY2002 – Qtr 3
	b. Conduct Experimental Fatigue Testing in Laboratory Fixture	0% Complete	FY2002 – Qtr 4 (Oct. 1 through Dec. 20)
	c. Conduct Experimental Testing in MTS Fixture	0% Complete	FY2002 – Qtr 4 (Oct. 16 through Nov. 27)
	d. Generate Statistical Data for Fatigue Life Prediction	0% Complete	FY2002 – Qtr 4 (Dec. 20 through Dec. 27)
14	Write Draft Report to WisDOT	20% Complete	FY2002 – Qtr 4 / FY2003 – Qtr 1 (Dec. 27 through Jan. 15)
15	Review Period for WisDOT	0% Complete	FY2003 – Qtr 1 (Jan. 15 through Jan. 30)
16	Final Report to WisDOT	0% Complete	FY2003 – Qtr 1 (Feb. 1 through Feb. 28)

**Note: Gantt chart shown in State Fiscal Year Quarters**

**State of Wisconsin/Department of Transportation**  
**RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Sep 30, 2002**

<b>Program: SPR-0010(36) FFY99</b>	<b>Part: II Research and Development</b>
<b>Project Title: Rehabilitation Techniques for Concrete Bridges</b>	<b>Project ID: 0092-01-06</b>
<b>Administrative Contact: Nina McLawhorn</b>	<b>Sponsor:</b>
<b>WisDOT Technical Contact: Stan Woods</b>	<b>Approved Starting Date: Jan 18, 2001</b>
<b>Approved by COR/Steering Committee: \$124,968.00</b>	<b>Approved Ending Date: Jul 18, 2003</b>
<b>Project Investigator (agency &amp; contact): Habib Tabatabai: UW-Milwaukee</b>	

**Description:** Research Project description:

Concrete bridges in Wisconsin and elsewhere have shown severe signs of deterioration due to aging and other detrimental factors. Considering the enormous cost and effort required to remedy bridge deficiencies, it is crucial that a concerted effort be made to develop and implement practical, effective and economical methods and guidelines for the repair and rehabilitation of bridges. These methods should include effective preventative maintenance measures to reduce the impact and severity of long-term deterioration. This proposal addresses repair and rehabilitation techniques and guidelines for reinforced and prestressed concrete bridges in the state of Wisconsin.

**RFP Statement**

With the aging of Wisconsin's concrete bridges, increasing evidence of partial or extended bridge deterioration is experienced throughout the state. Problems such as failure of expansion joints, deterioration of concrete at the vicinity of joints and abutments, corrosion of reinforcing and prestressing steel, damage to overhead beams/girders due to truck impact, and other effects exist and need to be corrected on a daily basis. It would be beneficial to the WISDOT maintenance personnel to develop guidelines and procedures for implementing cost effective and reliable rehabilitation techniques to bring Wisconsin's concrete bridges to acceptable service conditions. Performing a study to evaluate various rehabilitation methods developed and implemented elsewhere as well as further development of additional techniques to address specific problems related to Wisconsin's concrete bridges could enhance the economy and safe use of our bridges in the state.

Total Study Budget	Current FFY Budget	Expenditures for Current Quarter	Total Expenditures to Date	Percent Complete
<b>\$124,968.00</b>	<b>\$41,656.00</b>	\$0.00	<b>\$11,638.89</b>	<b>75 (%)</b>

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**Progress This Quarter:**

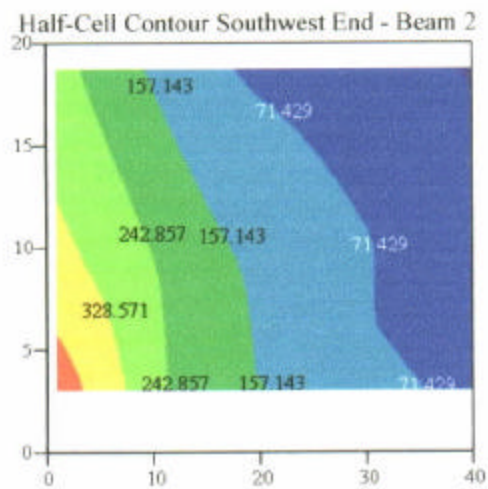
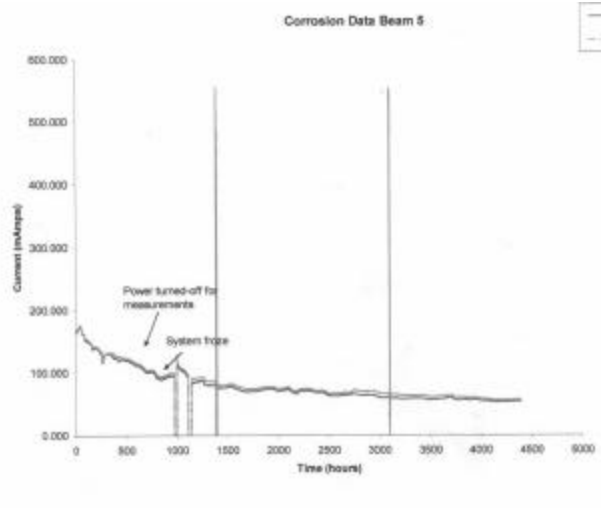
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

The test specimens have received over six months of accelerated corrosion exposure at this point. This is the length of time originally envisioned before application of repairs. The specimens have been subjected to 4 days of wet exposure (6% salt solution) and three days of dry exposure in each week.

Corrosion currents are being monitored with a data acquisition system. A sample corrosion current dataset is shown below. The observed corrosion current decay is similar to data available in the literature for field structures. Based on the literature data, it is estimated that the test specimens have an equivalent of 8 to 10 years of corrosion exposure in the field.

Preliminary analyses and plotting of corrosion and half cell data (up to this point) have been performed. A sample half cell contour is shown below. The red area (bottom flange area at beam end) shows higher potentials as expected. Although extensive corrosion is evident in the form of rust stains, cracking and spalling of concrete have not occurred yet.

Work on the software program continued. For this program, we are using the expert system shell program "CLIPS" developed by NASA. The program will ask a number of questions from the user and, based on a set of programmed rules, identifies a problem and recommends corrective actions. We are using a number of number of books, reports and papers as references in deriving the expert system rules. We contacted PCA to obtain permission to use their library of photos and slides in our program. PCA requested reimbursement for the use of their resources. We have therefore decided to generate our own drawings and photos instead, or utilize non-copyrighted materials.



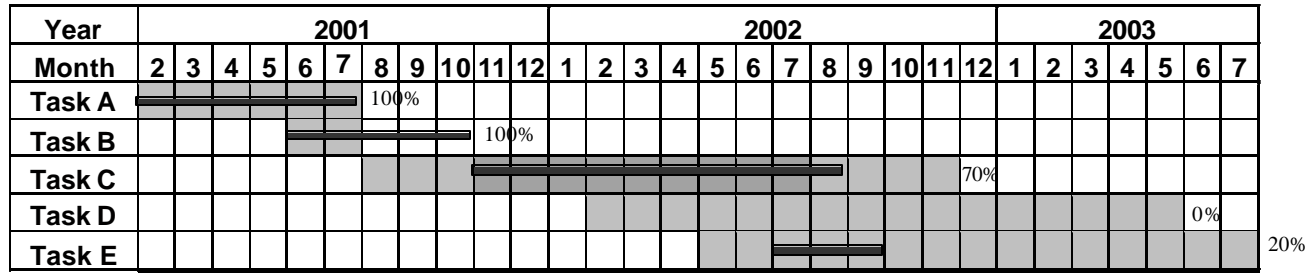
**Work Next Quarter:**




The original planned accelerated corrosion program is complete. Although cracking and spalling have not yet occurred on the beams, we will begin and complete planned repairs in the next quarter (based on the test matrix presented in the proposal). Following the repairs, the accelerated corrosion program will be re-initiated for another six months. Corrosion currents, half-cell potentials and displacement readings will be taken. Work on the software program will continue. The DOT will be contacted regarding field demonstration project.

**Circumstances affecting progress/budget:**

We are beginning the repair of beams shortly. The plan called for six months of accelerated corrosion following repairs. The duration of Task C will therefore be extended into 2003. However, the overall project completion is expected to remain unchanged.

**Gantt Chart:**



-  Planned (Original)
-  Revised Schedule for Revised Test Plan
-  Work Performed

Estimated Total Completion 75%

**Note: Gantt chart shown in State Fiscal Year Quarters**

**State of Wisconsin/Department of Transportation**  
**RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Sep 30, 2002**

<b>Program: SPR-0010(36) FFY99</b>	<b>Part: II Research and Development</b>
<b>Project Title: Rapid Strengthening of Reinforced Concrete Bridges</b>	<b>Project ID: 0092-02-14b</b>
<b>Administrative Contact: Nina McLawhorn</b>	<b>Sponsor:</b>
<b>WisDOT Technical Contact: Stan Woods</b>	<b>Approved Starting Date: Nov 7, 2001</b>
<b>Approved by COR/Steering Committee: \$59,069.00</b>	<b>Approved Ending Date: Nov 7, 2002</b>
<b>Project Investigator (agency &amp; contact): Larry Bank: UW-Madison</b>	

**Description:** This research study will use a new and innovative technique for rapidly strengthening reinforced concrete members with fiber reinforced plastic (FRO) strips will be demonstrated in a full-scale application on an existing bridge in the State of Wisconsin. The testing on the bridge will be preceded by a laboratory test program that will be used to determine the unstrengthened capacity of the bridge prior to ultimate load testing.

Total Study Budget	Current FFY Budget	Expenditures for Current Quarter	Total Expenditures to Date	Percent Complete
<b>\$59,069.00</b>	<b>\$29,534.50</b>	\$13,433.40	<b>\$0.00</b>	<b>82 (%)</b>

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**Progress This Quarter:**

(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

1. Meeting with the Common Council, City of Edgerton for approval of bridge

UW Representatives

Prof. Jeffery Russell  
 Mr. Dushyant Arora

DOT Representatives

Mr. Matt Murphy  
 Ms. Kim Johnson

On, August 5th, 2002. The UW research team along with the DOT representatives, presented in front of the common council, the scope of the research project in order to get the approval to conduct research on the city owned bridge.

The City of Edgerton's concerns regarding additional costs, the liability and safety of the project and personnel were answered during the course of the meeting and through mutual agreements between the DOT, The University of Wisconsin and the City of Edgerton.

The research team explained the details of the project and the long-term benefits associated with the research project.

The team further explained the different phases of the project that would be conducted on the bridge.  
 Phase 1: (August 19<sup>th</sup> – 30<sup>th</sup>, 2002) will be used to conduct the service load testing before and after the installation of the FRP strips and would involve no interruptions in traffic and would not involve any damage to the structure.

Phase 2: (Summer 2003) would incorporate the destructive testing of the bridge through a sub-contractor from the University of Missouri-Rolla a week prior to the demolition of the bridge. Specific items regarding the changed conditions of the structure would be explicitly detailed in the project specifications to reduce any additional costs to the DOT.

A unanimous and enthusiastic go ahead was given by the city council for the research project which was seen as a major cost saving measure for the city.

## 2. Bridge Testing

Under the time constraints from the DNR, any or all aspects of the research project were to be concluded by the 1<sup>st</sup> of September 2002. Work was completed in a two-week period from August 19 to August 30, 2002. Under the given time constraints and the unavailability of District 1 Maintenance personnel during the scheduled retrofit of the bridge, two personnel were provided from the county maintenance department. A third person was used for traffic control during the load testing and the installation of the strips.

A two-week schedule was organized for the Phase 1 of the project, which undertook the following tasks:

### Week 1

#### Day 1

Measure bridge dimensions.

Setup working platform under the bridge.

Clean the underside of the bridge.

Mark the location of the strips.

#### Day 2

Install strain gauges for service load test.

Mark location and position of truck.

#### Day 3

Setup up equipment for measuring strain under service conditions.

Conducted Static tests and rolling tests

#### Day 4

A local HILIT representative provided a quick demonstration and certification on the usage of power-actuated gun to the maintenance personnel.

Setup to install the FRP strips

Install FRP strips using the power actuated fastening system.

#### Day 5

Complete installation of 21 FRP strips using both aluminum and stainless steel fasteners and anchor bolts.

### Week 2

#### Day 6

Install strain gauges on the FRP strips.

Prepare for Service load test.

#### Day 7

Install LVDT's on the underside of bridge.

Conducted Service load tests.

Cleanup and remove equipment

Please see figures below of the tests and the installation process.



Figure 1. Load test



Figure 2. Installation of FRP strips on the bridge deck using Power Actuated System



Figure 3. Retrofit of Edgerton Bridge using Power Actuated System.

## **Work Next Quarter:**

### 1. Conduct Load Tests on Lab Specimens

Based on the preliminary analysis of the bridge, four 20" x 20" x 24 ft lab specimens were constructed in Q4. In Q1 02-03 the beams will be tested to measure the strength of a control specimen and ones with FRP strips to emulate the bridge retrofit.

Strains will be measured under a load-displacement test setup for the four specimens.

The first, the Control beam will be tested under four-point bending and the load-displacement data obtained.

The other three beams will be retrofitted with FRP strips and tested under similar setup and the strain, load-displacement data obtained.

### 2. Test Material Properties of "Safestrip"

The FRP strips acquired from Strongwell Inc. will be tested in the UW-structures lab to verify the material properties.

### 3. Analyses and Documentation of Data

Analyze Data from Phase 1 Service load tests

Analyze data from Lab specimens

Analyze Material tests data

Document Service Load tests

Document and Develop Installation/ Application guide for the DOT

Develop Final report of the project.

Evaluate efficacy of the system

#### **Circumstances affecting progress/budget:**

As indicated in the prior progress report the project was substantially delayed due to the fact that the DOT had difficulty identifying and then obtaining permission to use a bridge for the project. This has caused the project to be broken up into two phases: 1. Installation of FRP strips and service load testing and (2) ultimate load testing. The testing in first phase has been completed but the second phase testing will only be completed in the summer of 2002-2003 due to the construction schedule for the project.

Since the project was delayed because of the bridge selection issue the laboratory testing phase was also delayed (since the size of the bridge was not known the laboratory beams could not be tested to emulate the bridge). In addition, since the testing was only completed in August 2002 much analysis of the data and documentation of installation procedures still needs to be completed. Effectively, the delay has added 6 months of real work to the project.

However, on the bright side the fact that the FRP strips were installed this year and the bridge will be demolished next year provides an additional opportunity to investigate the long-term durability of the retrofit method. This is an added task that will need to be completed on the project.

Due to the delays experienced **an extension of the project period of performance to August 31, 2003 is requested.**

In addition, **a request is made for additional funding** to support the graduate student, Mr. Dushyant Arora on the project for an additional 6 months so that the work can be completed as required. Due to the delays Mr. Arora will not be able to graduate in December as planned but will only graduate next summer. This will severely impact Mr. Arora's financial situation. He is currently supported as a research assistant and obtains tuition remission as a result of this. The additional funds requested for 6 months of support for Mr. Arora that will enable him to complete the research and his MS studies are listed below.

50 % Research Assistantship (Jan – June 2003)	8,658
UW mandatory fringe benefits	1,299
UW mandatory tuition remission	2,165
UW indirect cost (15%)	1,818
<b>TOTAL supplemental request</b>	<b>\$13,940</b>

The PI requests that the DOT consider this supplemental request for funding in the WHRP program.

**Gantt Chart:**

2001- 2002												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Q1			Q2			Q3			Q4		
1. Advisory Committee	█											
2. Prelim Report												
3. Bridge Selection		█		█								
4. Lab Testing								█	█	█	█	█
5. Testing Plan							█					
6. Field Testing											█	
7. Data Analysis							█				█	█
8. Final Report												

2002-2003												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Q1			Q2			Q3			Q4		
1. Advisory Committee												
2. Prelim Report												
3. Bridge Selection												
4. Lab Testing	█	█	█									
5. Testing Plan												
6. Field Testing									█	█	█	
7. Data Analysis	█	█	█	█							█	█
8. Final Report				█	█	█	█	█	█	█	█	█

Key:    Black:            Task Completed  
           Hatched:        Ongoing Task  
           Grey:            Future Task

**Note: Gantt chart shown in State Fiscal Year Quarters**