# State of Wisconsin/Department of Transportation

**RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING:** Mar 31, 2002

| **Program: SPR-0010(36) FFY99** | **Part: II Research and Development** |
|---|---|
| **Project Title: Structural Analysis of Sign Bridge Structures and Luminaire Supports** | **Project ID:** 0092-00-16 |
| **Administrative Contact:** Nina McLawhorn | **Sponsor:** |
| **WisDOT Technical Contact: Error! Bookmark not defined.** | **Approved Starting Date:** May 3, 2000 |
| **Approved by COR/Steering Committee:** $49,969.00 | **Approved Ending Date:** May 3, 2002 |
| **Project Investigator (agency & contact):** Christopher Foley: Marquette University | |

**Description: Error! Bookmark not defined.**

| Total study budget | Current FFY budget | Expenditures for current quarter | Total Expenditures to date |
|---|---|---|---|
| **$49,969.00** | **$16,656.34** | **$0.00** | **$0.00** |

**Progress This Quarter:**

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

This quarter saw the finalization of the finite element models for the four sign structures discussed in the last quarterly report (ending Dec 31, 2001). These FE models were used to study the response of S-67-402, S-40-404, and S-40-156 when subjected to simulated turbulent wind gusts as well as the truck-induced gust pressure as discussed in previous reports. A series of turbulent wind simulations were conducted for wind speeds ranging from 5 to 50 mph. Since all structures were located in Milwaukee and Waukesha counties, this range of wind speeds studied covered 99.7% percent of all wind speeds measured at Mitchell International Airport from July 1996 through November 2001. Preliminary results of this analysis were presented at conferences in Wisconsin (Foley and Ginal 2002a) and at ASCE Structures Congress in Denver (Foley and Ginal 2002b). These presentations are available in MS Powerpoint on the Project web-site.

The simulations conducted allowed the development of stress range histograms for all details considered critical in the three sign support structures studied. These stress-range histograms will serve as the basis for fatigue life predictions for the sign support structures. Preliminary analysis of fatigue life based upon simple linear accumulation of damage using Miner's rule indicates that the lives are quite short for many details in these structures (too short given the in-service existence of the three structures studied). The S-N data used for this preliminary estimate of fatigue life assumed stress ranges for which 95% of the experimental results were greater than the stress range for any given number of cycles. It is well known that using 95% confidence interval S-N diagram data leads to highly conservative fatigue life predictions. Therefore, the S-N diagrams were adjusted to 70% and 50% confidence intervals (Moses, *et al* 1987). While this did improve the fatigue lives in many cases, there remain several details (including anchor bolts) that are "of significant concern". The concern is related to several issues: (a) there are "hot spot" details (specifically the welded pipe truss-web members) in the four chord and tri chord structures studied where fatigue life is very short (at least with the prediction methodologies used; (b) the experimental results for AASHTO category ET details are not well documented (*e.g.* it is difficult to find documented evidence of the experimental data such as mean stress ranges per numbers of cycles and coefficients of variation); (c) the anchor bolt fatigue life for S-67-402 is very short resulting from significant anchor bolt bending and axial stress during the simulated winds (this is the structure with very long anchor bolt stand off height and relatively thin base plates). These results are currently being written up as part of the MS Thesis of Mr. Scott Ginal at Marquette University to be defended shortly.

The natural wind simulation of these structures has led to much needed loading data (*e.g.* axial force, transverse shear forces, and bending moments) that will be used to guide the proposed fatigue testing which constituted a portion of the proposed work plan. The late stage (relative to the projected completion date – May 3, 2002) at which this data was attained makes completion of the project on the projected date impossible. The ramifications of this will be discussed later in this report.

The finite element models for the high-mast luminaire supports (HML-40-095, -40-086, -40-061, -67-006) developed in the last quarter were used to conduct simulated wind stress history analysis of the anchor bolts, mast-to-base-plate weld, mast-splice welds, and locations at the ends of the hand holes in the mast. Stress range histograms for these details were used to predict fatigue lives using 95% confidence interval stress ranges. These results were presented at conferences recently (Foley and Ginal 2002a, 2002b). The fatigue lives of these details were not of significant concern as in the case of the sign support structures. However, the PI is in the process of adjusting the fatigue life predictions for these structures to include 50% (mean) confidence intervals and 70% confidence intervals. Furthermore, the stress range histories and fatigue lives of the HML support anchor bolts are presently being evaluated.

*References*:

Foley, C.M. and Ginal, S.J. (2002a) "Fatigue Performance of Highway Sign Bridges and High-Mast Luminaire Supports", ASCE Wisconsin Section, 2002 Spring Technical Conference, Olympia Resort, Oconomowoc, Wisconsin.

Foley, C.M. and Ginal, S.J. (2002b) "Fatigue Evaluation of Full-Span VMS/CMS Support Structures Subjected to Simulated Truck-Gust and Natural Wind Turbulence", Proceedings of the 2002 Structures Congress and Exposition, Denver, CO, CD-ROM.

Moses, F., Schilling, C.G., Raju, K.S. (1987) "Fatigue Evaluation Procedures for Steel Bridges", National Cooperative Highway Research Program Report No. 299, Transportation Research Report, National Research Council, Washington, D.C., November.

**Work Next Quarter:**

The work to be conducted next quarter will include finalization of the fatigue life predictions of the sign support and luminaire support structures studied. As it stands now, the fatigue lives predicted using 95%, 70%, and 50% confidence interval S-N data for category E' and ET details are very short and far below the actual service lives that these structures have enjoyed. Therefore, a reliability-based approach to fatigue life prediction is presently being explored. Reliability-based fatigue life prediction methodologies will be explored for BOTH the HML supports and the full-span overhead sign support structures. While this effort will not be included in the work of Mr. Ginal and his MS Thesis, it will be part of the final project report. Mr. Ginal's thesis will include fatigue life predictions for full-span overhead sign support structures when subjected to truck-induced gust pressures and turbulent wind. The fatigue lives will be evaluated using 95%, 70% and 50% confidence interval S-N data. This MS Thesis will be referenced in the final WisDOT report.

The fatigue testing can now begin to be formulated for those details that are of concern within the structures considered in the project. Unfortunately, this testing will have to occur at a date beyond the original target completion date of the project. This issue will be the subject of a "no-cost-extension" to the project work to be filed with the WHRP.

There are several details that have arisen as critical to the success of predicting fatigue lives of the sign support structures. This fatigue life prediction can then be used to rationally assign inspection protocols. In the original work plane dated October 1, 1999, Figures 1 through 6 illustrate the proposed fatigue testing of the WT-Stub retrofit detail found in several structures. While this detail may be important to predicting fatigue life, there has not been any documented evidence that an in-service fracture of a WT member has occurred. However, there have been several instances where cracking has been found in the welded pipe web members of full-span sign supports and these welded details are appearing as *critical* entities in the severely shortened fatigue life predictions of these structures obtained from the analytical work.

The S-N diagram is by nature, a statistical entity. Experimental fatigue testing includes significant scatter in the number of cycles to failure for any given stress range for the test. The scatter band can be significant, especially when a log-log plot is used to illustrate the data (as in the case of AASHTO detail categories). Therefore, at any given stress range, it is not uncommon for the number of cycles to failure to vary by 100,000 cycles or more. This could mean the difference between a fatigue life prediction of one year and a fatigue life prediction of 5 or more years.

The present analytical work conducted for the full-span overhead sign supports is indicating that the fatigue lives of these structures is far less the service life that has been seen thus far for the structures studied. One way to create accurate fatigue life predictions is to "understand" and "quantify" the source of scatter in the fatigue test data reported in the literature. Most of the work on welded pipe structures has been undertaken by the off-shore oil industry. Past experimental efforts by this industry have resulted in fatigue detail categories ET, $K_1$ and $K_2$. These detail categories are not as well documented (in terms of statistical scatter of the data) as the AASHTO categories A, B, C, D, E, E', and F. Also, many of the radius-to-thickness ratios and diameter ratios commonly found in the offshore industry are not present in full-span overhead welded sign support structures. The work of Moses, *et al* (1987) discussed previously provides well-documented mean and coefficient of variation information for categories A through F. The body of research is sorely in need of similar work done for categories ET, which currently cover the welded pipe truss structure details. It is believed that the very short fatigue lives predicted using "averaged" statistical information from detail categories A through F for detail category ET may (at least) be partly responsible for the short fatigue life predictions found in the analytical work. Furthermore, this additional statistical information related to category ET will allow reliability-based procedures for fatigue life prediction to be generated. Without this statistical information, the DOT is limited to semi-deterministic S-N data, which can tend to result in irrationally over-conservative predictions of fatigue life.

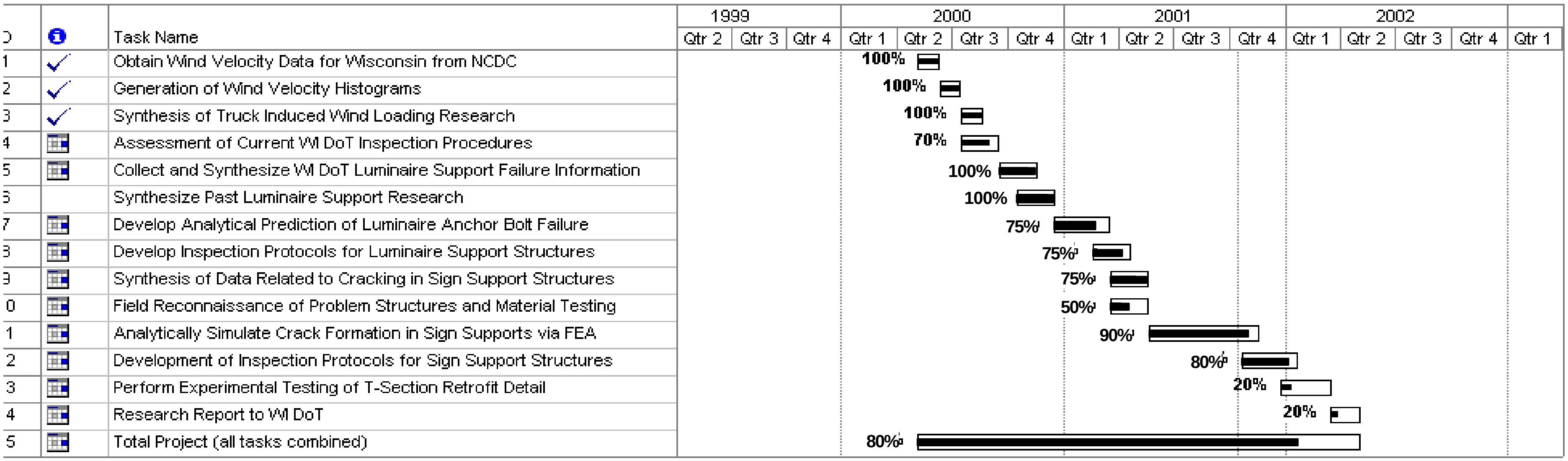
Work during the next quarter (discussed in the no cost extension) will include the following modified tasks from the work plan dated October 1999 (it should be noted that the project started one-year later than the work plan submittal. First of all, in lieu of performing fatigue testing on the WT-Stub retrofit detail, fatigue tests will be conducted to determine the fatigue life characteristics for the welded pipe truss connection for which the statistical information of the S-N diagram is so severely lacking. This is essentially detail category ET. The fatigue testing will include 6 specimens at a single stress ranges typical of the analytical results generated to this point in the research effort. These fatigue tests will be discussed with the Oversight Committee once the testing setup and protocol is established. The work will be carried out in the University of Wisconsin – Milwaukee structural testing laboratory over the summer months of 2002. Fatigue testing of anchor bolts which include base plate flexure will also be conducted. These tests will include 3 specimens at three stress ranges. The goal of the testing will be to validate the category D classification of the anchor bolts that include flexure from double-nut base plate connections, or suggest a modification for these components.

The results of the fatigue testing effort will be used to adjust the fatigue life prediction methodology used to this point in a manner that is supported by the additional experimental data. Furthermore, the experimental work that will be undertake will provide additional statistical information for category ET details so that reliability-based fatigue life predictions can be generated in a manner similar to that discussed in Moses *et al* (1987).

**Circumstances affecting progress/budget:**
From the preceding discussion, it is obvious that the research effort has been deliberate, but behind schedule. The late start to the project tended to set the schedule back significantly as the graduate research assistant "recruited for the project" (Mr. Ginal) could not come on board as early as the PI would have liked. Furthermore, the analytical work completed thus far suggests that the original plan to test the WT-stub retrofit detail should be substituted with fatigue testing of specimens. These circumstances have led the PI to request a no-cost extension for the work. This extension has been filed with Ms. Aileen Switzer of the WHRP.

**Gantt Chart:**

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



# State of Wisconsin/Department of Transportation

**RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING:** Mar 31, 2002

| **Program: SPR-0010(36) FFY99** | **Part: II Research and Development** |
|---|---|
| **Project Title: Rehabilitation Techniques for Concrete Bridges** | **Project ID:** 0092-01-06 |
| **Administrative Contact:** Nina McLawhorn | **Sponsor:** |
| **WisDOT Technical Contact: Error! Bookmark not defined.** | **Approved Starting Date:** Jan 18, 2001 |
| **Approved by COR/Steering Committee:** $124,968.00 | **Approved Ending Date:** Jul 18, 2002 |
| **Project Investigator (agency & contact):** Habib Tabatabai: UW-Milwaukee | |

**Description: Error! Bookmark not defined.**

| Total study budget | Current FFY budget | Expenditures for current quarter | Total Expenditures to date |
|---|---|---|---|
| **$124,968.00** | **$62,484.00** | **$0.00** | **$0.00** |

**Progress This Quarter:**
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)
The experimental test setup was completed and the accelerated corrosion has been initiated. All test specimen received their respective end protection treatments. The following is a summary of various end treatments:

- Fiber-reinforced polymer (FRP) treatment. The FRP material selected was Replark 30 produced by Mitsubishi Corp. of Japan and distributed by ABM corporation in New York. The is a carbon fiber composite that was also used in a major Canadian column corrosion study. One beam end was treated. A representative of ABM was available to ensure proper installation.
- Polymer treatment. The same polymer adhesive used in Replark was applied without carbon fiber sheets. One beam end was treated in this manner.
- Epoxy sealer (Masterseal GP produced by Masterbuilders) was applied on one beam end in accordance with manufacturer's instructions.
- Silane sealer (40% silane sealer produced by Masterbuilders) was applied on one beam end in accordance with manufacturer's instructions.
- The remaining six beam ends were left untreated. Some of these beam ends will receive treatment after the completion of initial corrosion process.

The baseline chloride content measurements were taken on one beam at a point in the center of the beam at various depths. These measurements indicated high initial chloride contents (on the order 0.04 to 0.07% of mass of concrete). The results were communicated to the producer. Additional chloride measurements will be made to verify results.

Each beam was set up on a support "dolley" that rested on four large casters. A test area within the structural laboratory was enclosed with plastic sheathing. A salt water distribution system including two reservoirs, piping, timer, solenoid valve, sump pump, etc. was set up within the enclosed area. The timer regulates the wet-dry cycles.

A set of ten 9-volt regulated power supplies provide the electric potential to accelerate corrosion in each individual beam end. The corrosion currents between strands and the electrically-isolated "cathode" bars are measured using a DATAQ data acquisition system.

Over 200 brass points for mechanical strain gages were attached to the sides of beams at 4-in spacing. Displacement between points are measured using a whittemore mechanical strain gage (precision of 0.0001 in). A number of other locations were marked on beams as points for half cell potential measurements. Initial measurements of all mechanical strain measurements as well as half cell potential measurements were taken before start of accelerated corrosion. In addition, a set of magnetic signature measurements were taken for comparison with future measurements at the end of all testing.

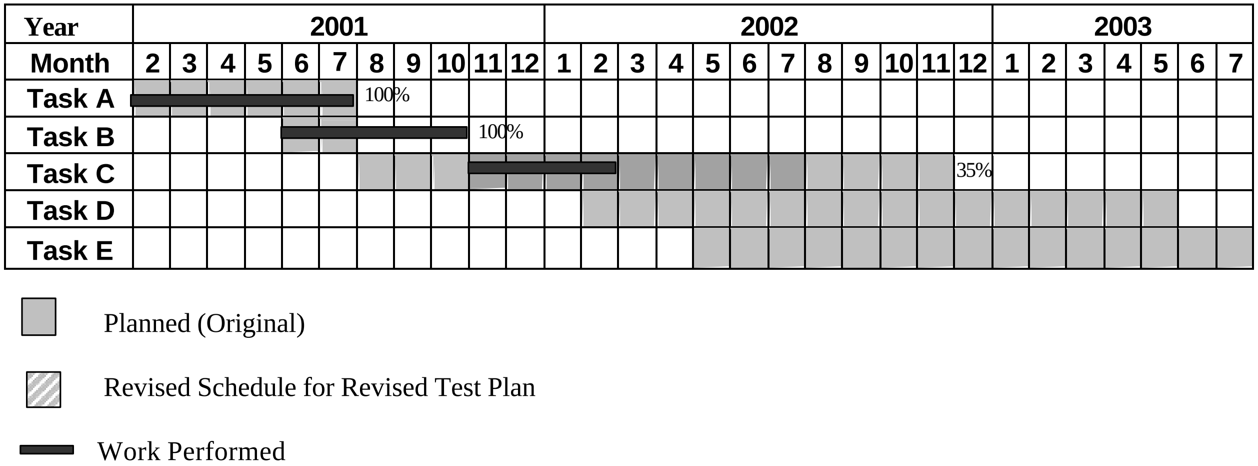
The software shell for the expert system program was selected. The Portland Cement Association was contacted to obtain their permission to use selected photos from their extensive photo and slide library for inclusion in the software.

**Work Next Quarter:**
The wet-dry cycles and applied electric currents will continue for the entire quarter. Periodic readings of mechanical strain points and half cell potentials will be made. Corrosion currents will be monitored approximately every hour using the data acquisition system.

Work on the software will continue. Expert system software work will continue. We will contact DOT regarding planning for field program.

**Circumstances affecting progress/budget:**
None.

**Gantt Chart:**




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

## State of Wisconsin/Department of Transportation

**RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING:** Mar 31, 2002

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

**Description: Error! Bookmark not defined.**

| Total study budget | Current FFY budget | Expenditures for current quarter | Total Expenditures to date |
|---|---|---|---|
| **$59,069.00** | **$29,534.50** | **$0.00** | **$0.00** |

**Progress This Quarter:**
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)
The progress on the contact is reviewed according the tasks detailed in the research contract and provided below:

Task 1 – Advisory Committee

Mr. Bruce Karow, Head of the Maintenance Division, at the Wisconsin Department of Transportation has been added to the Technical Oversight Committee for the project.

The Committee consists of:

Gerry Anderson, WisDOT
Bruce Karow, WisDOT
Bob Wysocki, HNTB
Al Ghorbanpor, UW-Milwaukee
Lawrence Bank, UW-Madison
Michael Oliva, UW-Madison
Dushyant Arora, UW-Madison
Antonio Nanni, University of Missouri-Rolla

Task 2 – Provide Preliminary Report on the Proposed Method

The details of the proposed method were presented to members of the WisDOT and DOT District 1 personnel at a kickoff meeting held at the University of Wisconsin on March 6, 2002 (see Task 3). Technical papers were provided to DOT officials with the first quarter report. An installation guide for the system is being developed.

Task 3 – Select the Bridge

A Project Kickoff meeting was held on March 6, 2002 at UW-Madison. The purpose of the meeting was to brief the DOT on the rapid strengthening method (see Task 2 above) and to finalize the bridge selection. Attendees were:

WISDOT Representatives:
Mr. Gerry Anderson
Mr. Kirk A. Konkel
Mr. Stan Woods
Mr. Bruce F. Karow

UW-Madison Representatives:

Dr. Lawrence Bank
Dr. Michael Oliva
Mr. Dushyant Arora
Capt. Dave Borowicz
Mr. Anthony Lamanna

At the meeting the UW team presented an overview of the project and the roles and responsibilities of the UW team and the DOT were discussed. A list of action items were developed at the meeting, as follows:

1. BRIDGE SELECTION:
The members of the DOT team and the UW team made the final selection of the concrete flat slab bridge - Bridge P-53-702, located in Rock County in the City of Edgerton. All members agreed upon this site as being the most suitable for the research. Mr. Konkel of District 1 was determined to be the most suitable person to obtain permission from the City of Edgerton to use the bridge for the project. The City of Edgerton, which owns the bridge will be informed of the research to be conducted on the bridge and permission will be obtained before any further action will be taken. The approval process with the City of Edgerton is currently in progress.

2. SITE INVESTIGATION:
The selected site was discussed in detail. Mr. Arora made a presentation of the existing conditions of the site. The Bridge, built in 1930 is a flat slab concrete bridge with a span of 23ft and a width of approximately 26ft. The presentation included the proposed application of the strengthening system on the bridge and discussion of coordination between the two teams.

3. PLANNING AND LOGISTICS:
The roles and responsibilities of the two teams were discussed and decided. This included the scheduling of the preliminary investigation of the site. Various responsibilities were distributed among the members of both teams that have since then been completed or are currently being worked upon. District 1 will assist with obtaining cores from the existing structure to determine in-situ concrete strength and rebar data.

4. STRUCTURAL ANALYSIS:
The structural analysis of the proposed bridge is currently being conducted. Inspection reports of the bridge were obtained to determine the details of the structure. Preliminary analysis was conducted to evaluate the existing strength and load rating of the structure. The bridge is currently rated at an Inventory Rating of HS 17 and an Operating Rating of HS 29. Preliminary calculations on the strengthening levels to be used have been conducted. Based on these calculations it has been determined that the bridge can be raised to an HS 20 Inventory Rating by attaching one FRP "SafStrip" at about 12 in oc and it can be raised to a HS 25 Inventory Rating by attaching two FRP "SafStrips" at about 12 in oc spacing. The UW team recommends the second option – i.e. strengthening the bridge to a HS 25 Inventory Rating.

Task 4 – Fabricate and Test Laboratory Specimens

The UW team has conducted preliminary designs for the beams to be tested in the summer of 2002 in the UW structures laboratory. Three beams measuring 20" x 20" x 24' will be tested. One control, one strengthened (static) and one strengthened (fatigue.) Final determination of the parameters of the test beams will be made when the strengthening level is decided and material property data for the in-situ bridge is obtained.

Task 5 – Develop Field Testing Plan

Preliminary plans for the service load testing and ultimate load testing have been developed. The service load testing will be conduced in the summer of 2002. The UW team proposes to do the strengthening and service load testing in early June 2002. The ultimate load testing (to be conducted in cooperation with Missouri-Rolla) will be conducted the following year – in the summer of 2003. District 1 will supply load trucks and traffic control for the service load testing. The UW team will supply the data acquisition system. The UW will also provide an installation specification for the strips and loan tools to the DOT personnel for the installation.

Task 6 – Bridge Testing

Service load testing will be conducted according to the plans developed in Task 5 in the next quarter.

Task 7 – Analysis of Test Data

Test data will be analyzed as it becomes available.

Task 8 – Final Report

A Final Report will be delivered at the conclusion of the project. As indicated the project will be completed in the summer of 2003 and not in the October 2002 as originally proposed. The extended schedule is due to the fact that the bridge is only scheduled for replacement in 2003. The DOT was not able to find a bridge for the project due for replacement in the summer of 2002.

**Work Next Quarter:**

In the Third Quarter (April – June 2002) the following will be conducted:

1. Permission will be obtained from the bridge owner.
2. The strengthening system will be designed and finalized.
3. An installation guide will be developed.
4. An installation specification will be developed.
5. FRP strips will be produced.
6. A service load test plan will be developed.
7. The strengthening system will be installed.
8. The service load testing will be conducted.
9. The laboratory beams will be fabricated.

Note: Tasks 7-9 depend on a number of coordination issues and may be delayed to the $4^{th}$ quarter (July – September 2002).

**Circumstances affecting progress/budget:**

The permission of the bridge owner must still be obtained. This is causing delays in the project schedule. It is hoped that the DOT will resolve this very shortly.

The entire project needs to be extended by 12 months since the bridge replacement will only be completed in 2003. A project extension request will be submitted to the WHRP for this purpose. Mr. Woods has indicated (verbally) that he does not see a problem with extending the project. This request will include a request for additional funding to provide finds to enable the UW team to conduct the ultimate load test and the data analysis and reporting related to the testing in the summer of 2003. In the original work plan the service load testing and the ultimate load testing were to be conducted in the same time frame (summer 2002). This would have allowed the UW team to acquire and analyze the data at the same time. With the separation of the service load and ultimate load testing resources will need to be provided to cover personnel costs for the work in 2003.

**Gantt Chart:**

| | 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 Competed
- Hatched: Ongoing Task
- Grey: Future Task

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