

State of Wisconsin/Department of Transportation
RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Mar 31, 2001

Program: SPR-0010(36) FFY99	Part: II Research and Development
Project Title: Non-Destructive Testing of Highway Bridge Structures for Purposes of Structure Evaluation	Project ID: 0092-00-15
Administrative Contact: Nina McLawhorn	Sponsor:
WisDOT Technical Contact: Error! Bookmark not defined.	Approved Starting Date: Dec 22, 1999
Approved by COR/Steering Committee: \$49,745.00	Approved Ending Date: Nov 30, 2001
Project Investigator (agency & contact): Al Ghorbanpoor: UW-Milwaukee	

Description: Error! Bookmark not defined.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
\$49,745.00	\$16,581.66	\$1,925.06	\$23,956.41

Progress This Quarter:

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

Description: This research will develop guidelines with recommendations for appropriate test methods for NDE of steel and concrete bridges in Wisconsin.

Literature review for NDE methods has been completed. A list of methods reviewed was included in the previous progress report. A summary of the methods has been prepared and will be included in the final report.

Continued laboratory studies on the ultrasonic, magnetic flux leakage, and impact-echo methods. These methods have shown greater potential for successful field applications.

The FHWA's inspection training manual has been reviewed and a summary has been prepared. The summary has been attached as an appendix to this report.

Field testing of post-tensioned concrete structures has been performed using the magnetic flux leakage method. It has been shown that the method is capable of detecting small corrosion in the tendons of post-tensioned concrete structures. Additional field testing with other NDE methods needs to be explored.

Work Next Quarter:

Continue the laboratory studies for the selected NDE methods as well as additional methods depending on the availability of relevant equipment. Initiate the preparation of the final report by assembling the various materials that have been researched to date. Discuss with the oversight committee the needs for field evaluation of a selected number of methods identified as those with greater potential for success.

Circumstances affecting progress/budget:

None.

Gantt Chart:

Gantt Chart updated for quarter 1, 2001 (period ending March 31, 2001)

MONTHS TASKS	2000				2001			
	Qr. 1	Qr. 2	Qr. 3	Qr. 4	Qr. 1	Qr. 2	Qr. 3	Qr. 4
Review of Literature	_____ (100% completed)							
Equipment Acquisition	_____ (80% completed)							
Lab. Evaluation	_____ (95% completed)							
Field Evaluation	_____ (35% completed)							
Develop NDE Program	_____ (40% completed)							
Final Report	_____ (Not started)							

Note: Gantt chart shown in State Fiscal Year Quarters

State of Wisconsin/Department of Transportation
RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Mar 31, 2001

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	\$16,656.33	\$586.94	\$5,009.21

Progress This Quarter:

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

Description:

The project entails analysis of sign and luminaire support structures with specific examination of loading conditions and fatigue behavior. The research will result in inspection criteria and performance prediction for these auxiliary structures. An examination of luminaire support failure(s) and poor in-service performance of overhead sign support structures will be conducted with recommendations of possible causes and solutions. An evaluation of the fatigue characteristics of retrofit and other details for sign support structures including experimental testing will be conducted.

Total Study Budget	Current FFY Budget	Expenditures for Current Quarter	Total Expenditures to Date
\$ 49,969 (3)	\$ 25,000	\$ 5,084 (1)	\$ 9,506 (2)

Notes:

1. This number has been "adjusted" to reflect total expenditures to date as recorded in Marquette University accounting reports as of 2/1/2001 for Grant Number 01410-73104. Total expenditures were given as \$ 4,422 on the last quarterly report filed. Therefore, \$ 4,422 + \$ 5,084 = \$ 9,506 (as listed above).
2. Current expenditures as recorded by Marquette University as of 2/1/2001 for Grant Number 01410-73104.
3. The total study budget is \$ 49,969 as indicated on the contract dated 5/3/00.

Progress This Quarter:

Two individuals worked on the project this quarter. The first is Scott Ginal. Mr. Ginal was hired onto the project last quarter and is acting as a graduate research assistant. His work has focused on the overhead sign support structure component of the project. This research work will form the basis of his MS Thesis. Mr. Ginal has completed a synthesis of past truck-induced gust loading research and has developed a "characteristic truck pulse" to be used in the fatigue evaluation of the sign structures. Furthermore, he has also obtained fabrication drawings for all sign structures considered for evaluation as part of the project (*ie.* all sign support structures included in the work plan filed). Approximately 15 support structure fabrication drawings have been obtained and he has begun the process of coalescing these drawings into representative groupings to select representative structures for detailed study.

The P.I. began the process of developing analytical FEA models for the luminaire support bases. The Core-Ten luminaire support "poles" (found to have poor performance in Milwaukee County) have been modeled using the ANSYS finite element program. An FE model which includes the pole, base plate, and anchor bolts has been created and "debugged". After discussions with Mr. Kent Bahler of WIDoT, it was decided to include "hand-hole" openings in the FE model. This was easily included into the model developed.

Previous work included cutting apart a decommissioned aluminum overhead truss structure (S-40-40). During the "dissection" of this structure, it was noticed that significant fit-up deformations were present in the diagonal and vertical members. Therefore, the P.I. began to look at fit-up stresses as a source of "initial cracking" in sign support structures. Mr. Terence Browne of Collins Engineers, Inc. (Cudahy, WI) relayed information to the P.I. regarding gusset plate cracking found in several other Mid-western states. It is believed that a steel structure subjected to the same degree of fit-up stresses as that found in the aluminum truss could develop liquid metal embrittlement

during the galvanizing process subsequently leading to cracking. Liquid metal embrittlement has been suggested as a possible cause of cracking in other WIDoT steel sign support structures.

A software package was purchased to convert AutoCAD files to IGES format. The sign support structures are drawn to scale in AutoCAD then converted to IGES (neutral file) format for subsequent import into ANSYS. This package will also be used to perform solid modeling conversions from AutoCAD to IGES when the other luminaire support and sign support base plate models are created.

Work Next Quarter:

The work that will take place during the next quarter will remain focused in two areas: (a) development of the FE models for the various sign and luminaire support structures; and (b) development of the apparatus needed for the physical testing to be undertaken later on in the research effort. As the P.I.'s academic duties lessen during the next quarter, he will focus much of his attention on the luminaire supports and the experimental fatigue testing arrangements at the University of Wisconsin – Milwaukee. The P.I. will also begin the process of obtaining fabricated specimens of the T-stub retrofit detail to be tested sometime during the third quarter of 2001. Mr. Kent Bahler of WIDoT has given the PI several fabrication companies that WIDoT has used in the past and he is in process of contacting these firms to (hopefully) donate specimens.

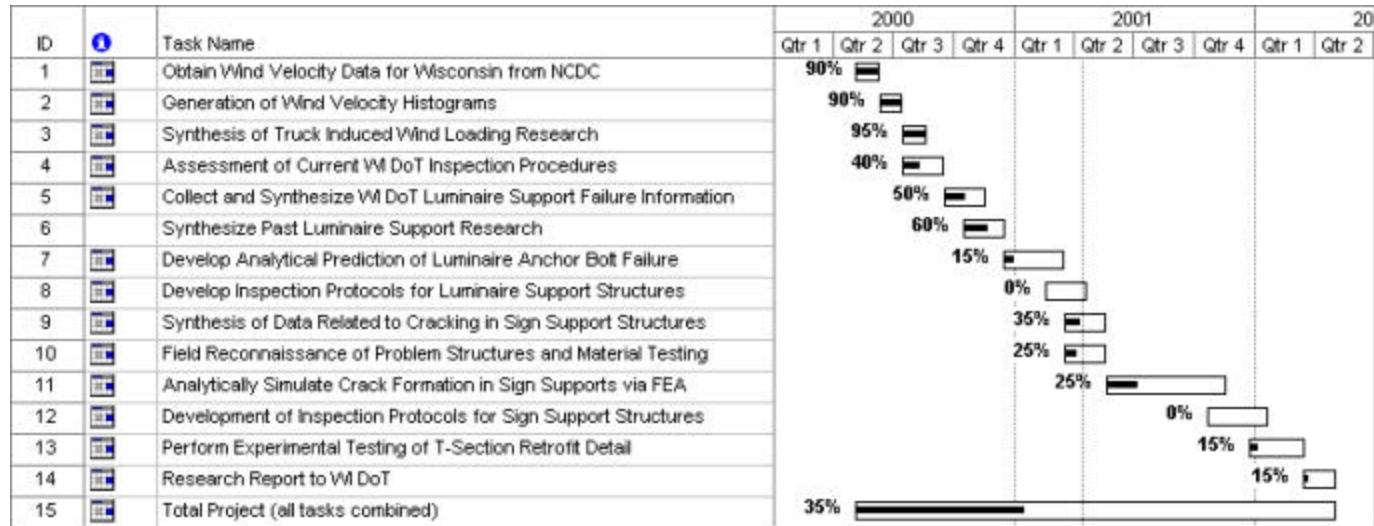
Mr. Ginal will continue his MS thesis research full time over the summer and next academic year and will concentrate on the sign support structures. He is in the process of studying methods with which fatigue analysis can be performed using ANSYS for naturally occurring and truck-induced wind gusts. There are presently two options available for natural wind gust analysis: (a) power spectral density (random vibration) analysis; and (b) time-history analysis using simulated wind loading. Each method has its merits and both must be thoroughly evaluated on the basis of the fatigue study to follow. The truck induced wind gusts are simply handled via transient impulse loading. Fit up stresses in these structures will be handled using thermal gradients over the pipe section diameter. FE modeling will easily allow these stresses to be quantified.

Circumstances affecting progress/budget:

There are no circumstances presently felt to affect the Project's budget. Wisconsin DoT personnel have been exceedingly accommodating in allowing the PI access to WisDOT intranet resources and also sign and luminaire support structure design, construction and fabrication drawings. The PI would like to make mention of several individuals that have helped thus far in an extraordinarily congenial and professional manner: Tom Heydel, Arlo Tessemer, and Charles Landey of the District 2 offices in Pewaukee, Wisconsin, as well as, Kent Bahler, Craig Wehrle, and Joel Aslum of the Madison DoT offices.

The researcher(s) have been unable to get structural steel specimens from decommissioned sign support structures. To this point, all the decommissioned structures have been aluminum from which specimens have already been obtained. The Kuehne Company and Arbor Green have been contacting the P.I. frequently to let him know when and if any steel support structures will be decommissioned and available for specimen collection. This may be a problem since Charpy V-Notch toughness data for material typically used in the sign support structures is useful for remaining fatigue life estimates. However, material used in these structures may be able to be obtained independently from actual decommissioned structures.

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, 2001

Program: SPR-0010(36) FFY99	Part: II Research and Development
Project Title: Assessment and Rehabilitation Strategies/Guidelines to Maximize the Service Life of Concrete Structures	Project ID: 0092-00-17
Administrative Contact: Nina McLawhorn	Sponsor:
WisDOT Technical Contact: Error! Bookmark not defined.	Approved Starting Date: Oct 1, 1999
Approved by COR/Steering Committee: \$50,000.00	Approved Ending Date: Sep 30, 2001
Project Investigator (agency & contact): Teresa Adams : UW-Madison	

Description: Error! Bookmark not defined.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
\$50,000.00	\$31,623.80	\$2,407.70	\$20,783.90

Progress This Quarter:

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

Meetings with District 5 on February 5, 2001, and District 1 on February 20, 2001

The Research Team met with bridge maintenance engineers from Districts 1 (Matt Murphy) and 5 (Edward Fitzgerald and Peter A. Luebke) for the purpose of discussing the deterioration methodology and for obtaining estimates of unit costs productivity, and service life of concrete deck maintenance strategies. The cost and productivity data of maintenance strategies are summarized in Table 1. The cost and productivity estimates will be used for life cycle cost analyses of various maintenance strategies. The service life of maintenance strategies will be used to calibrate the software tool (see Task 3).

Task 3. Mechanistic models of deck deterioration

This task is 70% complete.

The Research Team reviewed the software implementation (CORRODE) of Babaei et al. 1996¹ and spoke with the original project PI for developing the methodology, Ron Purvis. Ron Purvis advised the Research Team that the software program had some problems. No specific details were given. Since the CORRODE program is not customizable and the original source code is not available, the Research Team decided to develop an Excel spreadsheet that implements the mechanistic model for deck deterioration and a probabilistic life cycle cost analysis of maintenance strategies.

Figure 1 shows the spreadsheet interface for entering bridge data input. Deterioration is based upon a mechanistic model. (This is in contrast to the Pontis system that uses a stochastic model.) In this methodology, performance index (S) is defined as a function of percentage of concrete area delaminated, percentage of concrete area spalled, and percentage of concrete samples with bar-level chloride content higher than corrosion threshold value (0.035 percent of concrete weight), at that time. The model estimates future performance index based on initial S and other data that influence corrosion rate of the deck, such as depth of bar cover, concrete water-cement ratio, and surface chloride concentration. The predicted performance curve is used to estimate when the deck will deteriorate to the worst tolerable index. Figure 2 shows an example performance curve. In the spreadsheet, the performance curve of the deck is calculated automatically based on the input data.

¹ Babaei, K., Purvis, R.L., Clear, K.C., and Weyers, R.E. (1996). "Methodology for Concrete Removal, Protection, and Rehabilitation," prepared for the U.S. Department of Transportation, Federal Highway Administration, Wilbur Smith Associates, June, 270 pp.

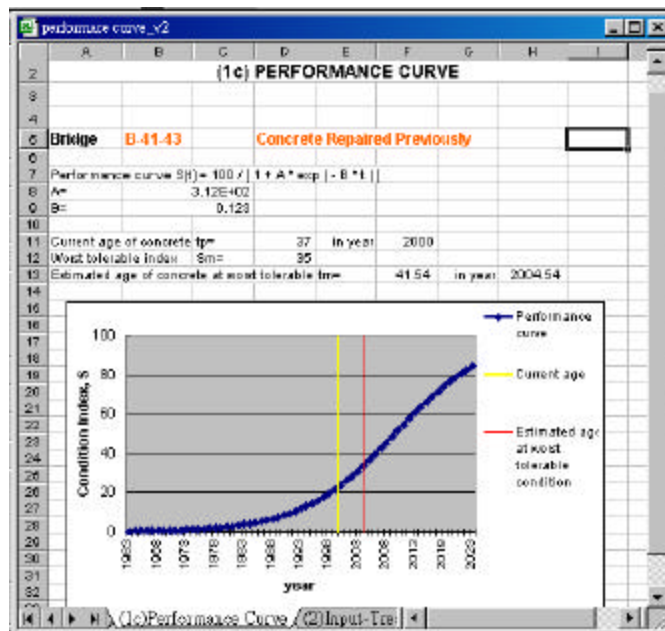
Table 1. Estimated Costs and Productivity of Concrete Deck Treatments

Treatment	Estimate d Service Life	District 5			District 1			Includes Traffic control	Includes Concrete Preparatio n	Note
		Cost Range (\$)	Unit	Productivity	Cost Range (\$)	Unit	Productivity			
Patching		10 ~ 20	ft ²					Yes	Yes	
					1.75 ~ 2.5	ft ²	16 ft ² / 0.5 day	No	No	
Patching with conquest rust inhibitor applied					2.75 ~ 3.5	ft ²	16 ft ² / 0.5 day	No	No	
AC overlay w/o membrane	2	5	ft ²					Yes	Yes	
					15 ~ 17	yd ²	40'*150' / day	No	Yes	
AC overlay w/ membrane	7	5 ~ 10	ft ²					Yes	Yes	
					18	yd ²	40'*150' / day	No	Yes	
Concrete overlay	15-20	10 ~ 20	ft ²	100ft *30ft / 30 days 200ft *30ft / 35~40 days	27 ~ 31	ft ²	Average bridge / 3 weeks	Yes	Yes	
					15 ~ 20	ft ²	Average bridge / 3 weeks	No	Yes	
Concrete masonry overlay		11	ft ³					No	No	1998 dollars
Removal of delaminated concrete		4	ft ²		5 ~ 15	ft ²		No	Yes	\$4/ft ² is in 1998 dollars
Application of sealer		0.25 ~ 0.4	ft ²		0.05	ft ²		No	No	
Full depth deck repair		19	ft ²					Yes	Yes	
Rehabilitation (redeck)	20	52	ft ²					Yes	Yes	
New deck	20				35 ~ 40	ft ²		Yes	N/A	

Figure 1. Interface entering bridge data

(1) Bridge Data Input (Chapters 5 and 6)	
Date:	3/24/2001
Bridge ID	B-41-43
Year (Re)Constructed (y0)	1963
Deck area (A)	6082 m ²
Year of survey (y)	2000
Percent of concrete area delaminated (DELAM)	10 %
Percent of concrete area spalled (SPALL)	10 %
Percent of concrete samples with low-level chloride content higher than 0.035 percent of concrete weight (CL)	100 %
Was concrete repaired previously?	<input checked="" type="radio"/> Repeated previously results in worksheets (1a) and (1c) <input type="radio"/> NOT Repeated previously results in worksheet (1b) and (1c)
For concrete REPAIRED previously only	
Year Repeated (y)	1978

Figure 2. Performance curve



Our spreadsheet application also deals with life cycle cost analysis of maintenance. We are implementing a probabilistic approach that includes risk assessment. The life cycle cost analysis of maintenance actions determines the optimum maintenance actions and timing. The most important factors that influence the life cycle cost are agency cost (cost of performing maintenance action), user costs (due to construction delays and deck condition) and estimated service life after the maintenance action is performed. The cost estimates obtained from Districts 1 and 5 show variability in costs. Therefore, cost is treated as a random variable with a triangular (min, most likely, max) distribution.

The service life of maintenance actions is dependent upon a variable K which models the change in the rate of corrosion (corrosion acceleration). K is defined as “the ratio of the slope of corrosion rate increase after treatment to the slope of corrosion rate increase before treatment” (Babaei et al. 1996). If the rate of corrosion continues to increase at the same rate (constant acceleration) after the maintenance, then K=1. If the rate of corrosion continues to increase after the maintenance, but at a slower rate (less acceleration), K is between 0 and 1. The value of K influences the service life

estimate of each treatment. Currently, there is insufficient data to define the variable K with accuracy. In our implementation, K is being treated as a random variable. Further analysis can be done to estimate ranges of K for various treatments by calibrating K using estimated service lives of the treatment.

The method simulates a new performance curve after maintenance. Monte Carlo simulation is performed to obtain a histogram of PV cost.

The spreadsheet is being developed and used to evaluate two existing decks in Wisconsin. The bridges selected are B-41-43 in District 5 and B-35-10 in District 7. These bridges were chosen because field test results of the chloride content of the decks (a necessary input data item of the methodology) were available. The chloride tests were performed in the 2000 and 1999, respectively. Detailed inspection reports for these two bridges were obtained from District 5 and the Central Office.

Task 4. Maintenance actions for concrete decks

This task is 85% complete.

The Research Team identified a number of life cycle maintenance strategies for concrete bridge decks. Matt Murphy (District 1) suggested some of the scenarios. A few possible scenarios are listed below.

1. Perform concrete overlay and then deck replacement, cyclically.
2. Perform cycles of patching until deck needs to be replaced, and then replace the deck.
3. Performance cycles of patching, then apply AC overlay, and then replace the deck.
4. Perform AC overlay and then melt-resurface the deck, cyclically.
5. Do no maintenance until deck need to be replaced, and then replace the deck.
6. Remove spalled concrete, perform chloride extraction and patching. Perform periodic chloride content tests and chloride extraction as needed until deck replacement.
7. Remove delaminated layer of concrete, perform chloride extraction and provide a concrete overlay with corrosion inhibitor.
8. Remove deteriorated concrete, patch or apply a concrete overlay and provide a cathodic protection system.

Scenarios 1 through 5 are some of the maintenance actions performed routinely by the DOTs in Wisconsin or elsewhere in the country. Scenarios 6 and 7 are fairly recent alternatives that may have not been applied in the field yet, but that offer potential economical and practical benefits. Scenario 8 is often considered too expensive and impractical, but it has been included here to serve as a means of comparison to the other scenarios under a common methodology.

The Research Team is collecting the necessary data cost, productivity, and service life data for performing life cycle cost analysis of these scenarios. The possible range of maintenance costs and K factors will be evaluated. Maintenance costs and K factors (corrosion acceleration) will be treated as random variables in a Monte Carlo simulation to perform life cycle cost analyses. A histogram of present value of cost will be produced.

Task 5. Prepare field inspection guidelines

This task is 25% complete.

This task focuses on field data collection procedures and implementation of the computer tool that will be the product of this research effort.

The Research Team identified the field inspection data that must be collected to support mechanistic deterioration modeling. The Research Team has also begun to develop the user interface for our computer application.

Work Next Quarter:

Task 3. Mechanistic models of deck deterioration

During the next quarter, the research team will continue to develop and test the spreadsheet application using the two bridge decks selected for study.

Task 4. Maintenance actions for concrete decks

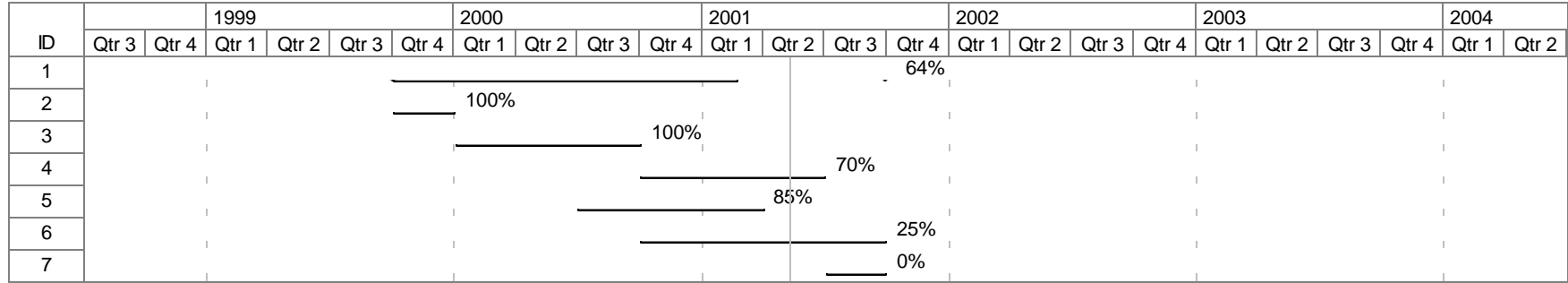
The Research Team will continue to develop the necessary unit cost and productivity factors for life cycle cost analysis of concrete deck maintenance.

Task 5. Prepare field inspection guidelines

The Research Team will prepare field inspection guidelines for collecting data to support mechanistic modeling of concrete deck deterioration. The Research Team will also begin to prepare a User's guide for the software application. The user guide will illustrate the procedure using the two case studies.

Circumstances affecting progress/budget:

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, 2001

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, 2003
Project Investigator (agency & contact): Habib Tabatabai: Error! Bookmark not defined.	

Description: Error! Bookmark not defined.

Total study budget	Current FFY budget	Expenditures for current quarter	Total Expenditures to date
\$124,968.00	\$41,656.00	\$0.00	\$0.00

Progress This Quarter:

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

This project officially began on January 18, 2001. The first task (Task A) in this project involves a comprehensive review of available literature. At the present time, a computer search of available information has been completed. Several hundred papers were identified. Those papers were screened. The title, abstract, source, author information, etc. of a total of 323 papers were imported into a searchable database (Microsoft Access program). This database allows researchers to quickly identify papers based on keywords within their titles or abstracts, or based on any number of other input fields.

Copies of approximately 300 papers were obtained from UWM library and through interlibrary loan. These papers are gathered in a file. Each paper has an identification number. At this point, papers related to repairs using Fiber-Reinforced Polymer (FRP) composites have been summarized into a report. Important progress is also achieved on summarizing bridge deck repairs and epoxy repairs.

Work Next Quarter:



The process of summarizing the literature search findings will be completed. The regional DOTs will also be contacted for an informal survey of their practices. An evaluation and test plan (Task B) will be prepared and the Project Oversight Committee will meet. The evaluation and test plan will be submitted to the Committee for review and comment. The Committee comments will be incorporated into the evaluation and test plan.

Circumstances affecting progress/budget:

There are no circumstances to report at the present time.

Gantt Chart:

Year	2001												2002												2003												
Month	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7							
Task A	Work Performed					Planned		70%																													
Task B					Planned																																
Task C							Planned																														
Task D														Planned																							
Task E																	Planned																				

 Planned
 Work Performed

Note: Gantt chart shown in State Fiscal Year Quarters