



## Semi-Annual Progress Report

**Date of Report:** August 31, 2009      **Project Number:** 9-4973      **RMC:** 5

**Period Covered:**     September 1, 2008 – February 28/29     March 1 – August 31

**Project Title:**      Guidelines for Designing Bridge Piers and Abutments for Vehicle Collisions

**Research Supervisor** (name & agency):    C. Eugene Buth, TTI

**Please see note about contract modification at the end of this report.**

- 1. Progress to Date, by Task** (Provide the following information for each task in the current Work Plan. List **all tasks**, even if no work was done during this reporting period. If a task was not active during this period, state “none” under Work Accomplished. Copy the following table as needed to cover all tasks.)

<b>Task #</b> 1a.	<b>Task Name / Description</b> Literature Review
<b>% Complete</b> 100	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b> <i>Technical Memorandum was submitted to RTI September 17, 2009</i>
<b>Work Accomplished this Period</b> (Brief description of work done and any major problems encountered.) None	
<b>Work Planned for next Reporting Period</b> (Brief description of work planned.) Researchers will continue to monitor literature.	

<b>Task #</b> 1b.	<b>Task Name / Description</b> Computer simulations of vehicle/bridge column and abutment collisions
<b>% Complete</b> 100%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b> <i>Technical Memorandum was submitted to RTI August 25, 2009</i>

**Work Accomplished this Period** (Brief description of work done and any major problems encountered.)

TTI researcher measured the dimensions of an existing trailer as well as collected information from online web sites of manufactures of such trailers. Then the TTI research team constructed the trailer model along with needed mechanism for the rear tandem axels and king pin to fifth wheel interactions. Material properties of the trailer bed and other components were assigned to reflect the proper physical behavior of such components. Contacts were defined to capture the physical impact phenomena among the components of the tractor and the trailer bodies.

Once the tractor trailer model was complete, several simulations were conducted to measure the impact force exerted on a 36" rigid column using both rigid and soft ballast for a total vehicle weight of 80 k lbs. Velocities of 40, 50, and 60 MPH were evaluated. Results for peak forces dues to engine block impact and ballast impact are listed in the table below.

Tractor Trailer Simulation Matrix Results Summary						
	Pier Diameter	Vehicle (Weight)	Cargo/Ballast	Impact Speed	Force (Kips)	
					Engine Block	Ballast
<b>Matrix IV</b>	36"	Tractor-Trailer (80 k-lb)	Deformable	40	520	800
	36"	Tractor-Trailer (80 k-lb)	Deformable	50	580	
	36"	Tractor-Trailer (80 k-lb)	Deformable	60	600	1020
<b>Matrix V</b>	36"	Tractor-Trailer (80 k-lb)	Rigid	40	500	> 500
	36"	Tractor-Trailer (80 k-lb)	Rigid	50	550	> 2000
	36"	Tractor-Trailer (80 k-lb)	Rigid	60	600	> 2000

Special simulation cases were conducted to evaluate the integrity of the recommended installation. Detailed modeling of the support structure and the foundation was implemented in these simulation cases. The results of these simulations were used to finalize the design details of the recommended installation.

**Work Planned for next Reporting Period** (Brief description of work planned.)

None

<b>Task #</b> 1c.	<b>Task Name / Description</b> Accident survey and analysis study
<b>% Complete</b> 100%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b> <i>Technical Memorandum was submitted to RTI August 25, 2009</i>

**Work Accomplished this Period:** Performed analytical pier shear capacity calculations for pier sizes ranging from 30 to 72 inches to investigate the impact strength of larger piers. Please refer to Table 1 for additional information

<b>Table 1 - Calculated Shear Capacities For Different Pier Diameters</b>			
<b>Pier Dia. (in.)</b>	<b>Design Con. Comp. Str. (psi)</b>	<b>Shear Reinfor. Size</b>	<b>Calc. Shear Cap. (kips)</b>
24	3600	#3 - 6 " Pitch	230
30	3600	#3 - 6 " Pitch	319
36	3600	#3 - 6 " Pitch	422
42	3600	#3 - 6 " Pitch	538
48	3600	#3 - 6 " Pitch	668
54	3600	#3 - 6 " Pitch	812
60	3600	#3 - 6 " Pitch	970
66	3600	#3 - 6 " Pitch	1142
72	3600	#3 - 6 " Pitch	1327

**Work Planned for next Reporting Period** (Brief description of work planned.)

None.

<b>Task #</b> 1d.	<b>Task Name / Description</b> Development of a risk analysis methodology for vehicle/bridge column and abutment collisions (analogous to AASHTO LRFD vessel impact requirements)
<b>% Complete</b> 100%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b> <i>Technical Memorandum was submitted to RTI August 25, 2009</i>

**Work Accomplished this Period** (Brief description of work done and any major problems encountered.)  
 The purpose of this task is to develop a methodology for estimating the risk of a collision between a heavy vehicle and bridge columns. Over the last five months, the research team collected crash data involving heavy vehicles (three axles or more) running-off-the-road and heavy vehicles hitting a bridge pier located on principle arterial highways in Minnesota, both controlled and non-controlled access facilities. The data collection also included information about the location of bridges on these highway segments that was provided by Minnesota Department of Transportation (MnDOT). Five years of data were collected (2002-2006). The crash and network data were collected from the Federal Highway Administration's (FHWA) Highway Safety Information System (HSIS), maintained by the University of North Carolina. The sample size consisted of 54 undivided segments and 552 divided segments.

Using these data two series of analyses were conducted. The first one consisted in developing a risk analysis methodology based on conditional probabilities, which involves the risk for a heavy vehicle to leave the traveled-way, and once it leaves the traveled-way, the probability for the vehicle to hit a bridge pier. The second methodology aimed at developing predictive models to estimate the risk for a heavy vehicle to hit a bridge pier as a function of the number of bridges crossing on top of the segments under study as well as other roadway characteristics.

In addition to the analysis with Minnesota data, the research team also prepared the final draft of the report.

**Work Planned for next Reporting Period** (Brief description of work planned.)

Given the results with Texas data, the similar analyses for estimating the risk for a heavy vehicle to leave the traveled-way, and once it leaves the traveled-way, the probability for the vehicle to hit a bridge pier will be carried out with the Minnesota data. These results will then be used to compare the risk between the two states.

<b>Task #</b> 1e.	<b>Task Name / Description</b> Detailed justification and work plan for research (if any) to be conducted under Phase 2 of the project
<b>% Complete</b> 100%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b> <i>Technical Memorandum was submitted to RTI August 25, 2009</i>

**Work Accomplished this Period** (Brief description of work done and any major problems encountered.)  
 Concepts for a crash test matrix were determined in the project meeting listed under Task 1e. The crash test matrix for phase 2 was approved by the project sponsors. Please see the information listed in the work accomplished for Task 1e for additional information.

**Work Planned for next Reporting Period**

None

<b>Task #</b> 1f.	<b>Task Name / Description</b> Provide facilities and host a meeting to present Phase 1 results to project sponsors, including pooled fund project contributors from other state DOT's
<b>% Complete</b> 100%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b> <i>Technical Memorandum was submitted to RTI August 25, 2009</i>

### **Work Accomplished this Period:**

A meeting was held on April 14, 2009 at the TTI Gilchrist Office Building to discuss Phase 1 analyses results and the crash testing options. Sixteen members including researchers from TTI and the pooled fund states participated in this meeting. The purpose of this meeting was to discuss the results/finding from Phase 1 and plan the work for Phase 2. The following items were discussed at this meeting.

- 1) Gregg Freeby with TxDOT gave a presentation on the overview of the project. A copy of this presentation is included with these meeting minutes in pdf format.
- 2) William Williams with TTI gave a presentation on Tasks 1a & 1c of the project. A copy of this presentation is included with these meeting minutes in pdf format.
- 3) Akram Abu-Odeh with TTI gave a presentation on Task 1b of the project. A copy of this presentation is included with the meeting minutes in pdf format.
- 4) Srinivas Geedipally with TTI gave a presentation on Task 1d of the project. A copy of this presentation is included with the meeting minutes in pdf format.
- 5) David Kiekbush with Wisconsin DOT indicated that Wisconsin currently uses 3'x5' columns to address the 400k load provision. Local FHWA officials in Wisconsin are requiring this.
- 6) Sue Hida with Cal Trans (AASHTO T-5 Chair) expressed concerns about requirements for retrofit solutions might be very different than requirements for new designs. Focus should be on new designs. Use of in-fill walls could be a problem with regard to meeting seismic requirements.
- 7) Art Yannotti with NY DOT indicated that New York has had at least one impact on a rectangular column.
- 8) Loren Risch with Kansas DOT observed that TxDOT spiral reinforcement in columns is very light compared to what Kansas provides.
- 9) Sue Hida offered that the column strength calculations should use AASHTO LRFD not ACI. Researchers will need to look at the AASHTO shear design methods and use the one most appropriate.
- 10) William Williams gave a presentation on the preliminary testing options developed for Phase 2 of the project. Four testing concepts were presented and discussed. Concept 4 was selected as the preferred testing option for this project. This concept consists of rigid pier supported by a rigid frame and instrumented with load cells to measure the impact force from the vehicle. A copy of this presentation is included with these meeting minutes.
- 11) Gene Buth with TTI indicated it is very difficult to determine the force in a crash test if the test article, in this case a concrete column, fails.
- 12) Testing will be performed on Design Concept 4 using a 80,000 lb tractor trailer with a deformable ballast at 50 mph. The second crash test will likely use an 80,000 lb tractor trailer with a deformable ballast at a speed to be selected after the project team reviews the results from the first test.
- 13) Gene Buth & Roger Bligh both agreed that the ultimate design force (currently 400 kips) should only be applied in the direction of travel. Current specification requires the force to be applied in any direction. This recommendation will be included in the final report.
- 14) The meeting adjourned.

Work commenced after April 14, 2009 on the design and details of the full-scale crash test installation for Phase 2 of this project.

### **Work Planned for next Reporting Period**

None

<b>Task #</b> 2a.	<b>Task Name / Description</b> Crash testing with a single unit truck to verify loading from Phase 1 literature survey and computer simulations. (The Project Team Determined from April 14, 2009 Meeting to perform 1 <sup>st</sup> Full-Scale Crash Test Using 80,000 tractor trailer with an impact speed of 50 mph).
<b>% Complete</b> 15%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b>
<b>Work Accomplished this Period</b> (Brief description of work done and any major problems encountered.) After the April 14, 2009 meeting, design of the full-scale crash test installation was started. Preparation of detailed drawings for the selected full scale test installation was also started. These drawings and details were completed on June 22, 2009. The full scale test installation for this project consists of a 36-inch diameter steel pier attached to two instrumented load cells. The completed test installation drawings were posted on the web for bidding purposes by contractors. Three bids were received for this project.	
<b>Work Planned for next Reporting Period</b> (Brief description of work planned.) Selection of the contractor and construction of the test installation at the TTI testing facility	

<b>Task #</b> 2b.	<b>Task Name / Description</b> Crash testing of a 5-axle tractor trailer rig to verify loading from phase 1 literature survey and computer simulations
<b>% Complete</b> 15%	<b>If task is complete, state when Technical Memorandum was submitted to RTI</b>
<b>Work Accomplished this Period</b> (Brief description of work done and any major problems encountered.) Same as Task 2a. A second crash test involving a tractor trailer will be performed after reviewing the results from the crash test performed for Task 2a.	
<b>Work Planned for next Reporting Period</b> (Brief description of work planned.) Construction of the test installation and full-scale crash testing will be performed the next reporting period.	

## 2. Progress to Date, by Deliverable

<b>Deliverable #</b>	<b>Deliverable Description</b>	<b>Progress to Date &amp;/or Date Submitted to RTI</b>
P1	Guidelines supplementing current AASHTO LRFD Specifications for collision loads on piers and abutments, including example utilizing proposed methodology	Due 2-28-10 None
P2	Presentation materials in suitable format for use in introducing concepts and new methodology to bridge design engineers.	Due 2-28-10 None
R1	Research report comprehensively documenting all phase 1 work performed, including recommendations for Phase 2 work (if any).	Due 04-30-10 90% completed
R2	Research report comprehensively documenting all Phase 2 work performed (if Phase 2 is conducted).	Due 04-30-10 None

PSR	Summary of work performed, findings, and conclusions.	Due 04-30-10 None
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**3. Equipment Purchases**

Description of Equipment	Date Purchased	Task and / or Deliverable Directly Related to Equipment Purchase
No Equipment Requested		

**4. Meetings / Conferences** (List any project meetings or conferences that were conducted during this reporting period and / or are planned for the next reporting period.)

Date & Time	Location	Purpose of Meeting / Conference
April 14, 2009	Texas Transportation Institute Gilchrist Office	Reviewed Phase 1 progress and planned Phase 2 work with representatives from participating states.

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