QUARTERLY PROGRESS REPORT

April 1, 2011 to June 30, 2011

As noted in the previous quarterly progress report, two new phases of wind tunnel testing were planned to take place at the National Research Council (NRC) of Canada in Ottawa, Ontario. This research was to be performed under two task orders through our lab support contract for the Aerodynamics Laboratory and is entirely funded by FHWA. The first of these, Phase 4, began on May 4 with setup of the large section model and rig in the 3m x 6m wind tunnel. Harold Bosch of the FHWA was present for much of the testing during the period May 10-18, 2011. See copy of his trip report, included below, for observations during this test period.

U.S. Department of Transportation
Federal Highway Administration

HRDI Trip Report

Traveler's Name:	**Routing Code:**	**Dates of Travel:**
Harold R. Bosch	HRDI-50	May 9-19, 2011

Destination:
Ottawa, Ontario, Canada

Purpose:
To participate in testing of large scale section model of a bridge stay cable in the M16 Wind Tunnel (3m x 6m) at the National Research Council (NRC) Canada.

List important information/results obtained from your trip.
Hands-on participation in the wind tunnel testing was extremely informative. The cable model was 6.69 m long and 161.7 mm in diameter and mounted on springs at an inclination angle of 60 degrees. The springs were carefully tuned at a frequency ratio of 1.0 and oriented to align with the heave and sway axes. Prior to testing the test rig was modified to allow rotation of the pipe about its longitudinal axis. As it turned out this feature was vital during this test phase. The smooth cable surface was outfitted with a double helical fillet representative of those used on many new bridge cables. Approximately 200 test runs were performed during Phase I. Most of these were conducted with minimal structural damping in the test rig and all test runs were in smooth approach flow. Initially, the model was tested by rotating the model on its axis while keeping the spring orientation fixed. It was noted that response was very sensitive to the pipe orientation with relatively large sway vibrations of 70 mm occurring at a rotation of -90 degrees. This was likely due to the out-of-roundness of the HDPE pipe, which is quite common on actual stay cables. For the model, the OOR was approximately 1-3 mm. Tests were performed over a wide wind speed range from 4 to 38 m/s, generally with the speed increasing; however, some tests were repeated with the speed decreasing to check for hysteresis. For some tests, the model was held and released or manually excited to look for changes in behavior. In addition, tests were run with the springs rotated to change the wind yaw angle or with the springs locked to measure forces on the fixed cable. In the latter stages of tests, damping was increased in the test rig. With the added damping, vibrations were not eliminated, but amplitudes were reduced and the motions became more disorganized.

List important actions you took or information you presented during trip.
Met with Drs. Guy Larose, Annick D'Auteuil, and Robert Wardlaw of NRC as well as Stoyan Stoyanoff of RWDI and Jasna Jakobsen of UIS to discuss and revise the test plan as testing proceeded and data was analyzed. Also communicated via email on a continuous basis with John Macdonald of UB (since he

could not attend due to an injury prior to testing) to get his reactions to test observations and suggestions regarding adjustments to the test program and data analysis. Near the conclusion of my visit and based upon observations during testing, it was decided to proceed with a Phase II of testing immediately following this test program. This would minimize setup costs substantially. Based upon remaining wind tunnel time for Phase I, a test plan for effective utilization of remaining resources was detailed and finalized. With the overall scope of the Phase I tests known, a detailed test plan for a Phase II of testing was formulated so that preparations could be made at NRC and tests could proceed immediately.

List required or recommended follow-up actions (if any)

Continue to monitor key observations and completion of remaining Phase I tests upon my return to TFHRC. Following completion of Phase I, monitor progress on Phase II testing and provide input regarding observations or changes to the test plan as needed. Arrange for transfer of all data and records following completion of testing. Review and comment on test report(s) when submitted.

As noted in the above trip report, the test plan for Phase 4 was continuously adjusted and fine tuned based upon detailed observations and review of data analysis results. Prior to his departure and prior to completion of this phase, Mr. Bosch (based upon his direct observations and discussions with the research team) decided to proceed with the next test series, Phase 5, immediately following the ongoing work. The wind tunnel and staff was available and the test rig (with model) was already installed in tunnel. A detailed test plan was developed prior to his departure. The second series of tests was completed on June 24, 2011. These tests focused on additional cable orientations as well as the influence of turbulence on cables with and without a helical fillet. Please see informal comments below from Dr. Larose (NRC) summarizing preliminary observations following completion of both phases of testing.

Comments by Dr. Guy Larose of NRC

{We are in the process of first updating the summary list of tests, completing the data reduction and writing a summary technical report. There is a lot to do and it will take a long time to comprehend the whole thing. We will have the summary list of tests with us in Amsterdam (attending ICWE13) and we should put some time aside to debrief you from the time we added turbulence onwards.

In a nutshell, at 60 deg. inclination, low damping, the model is simply prone to wind induced vibrations with unacceptable amplitudes. This is true for the case with or without added turbulence, with or without helical fillet. I now strongly believe that we are at a crossroad and we have to get away from the HDPE pipe and the current cable in situ fabrication technique. H. Yamada from Japan was here for a visit and he confirmed that Japan has now banned the helical fillet as a mitigation device and that the cable with dimples that they are using are also prone to vibrations when inclined, with or without rain. They are also looking for another solution and are asking for ideas! Yamada will be in Amsterdam (ICWE13).

We obtained a turbulence level between 3.5% and 5% with the inclined ladders. The cable model still underwent wind induced vibrations with the helical fillet in turbulent flow, and in some cases, the amplitude were larger than in smooth flow. The TrBL1 regime was still present, but at a lower wind speed as it could be expected. At higher speeds, we saw often strong sinusoidal end-to-end motion apparent to vortex induced vibrations. So turbulence is not necessary beneficial and is not the key.

In general, removing the helical fillet caused an increase of the vibrations in terms of amplitude and frequency of occurrence. Removing the turbulence and the helical fillet translated in wilder vibrations, up to 90 mm amplitude for some of the cable rotation angles. Our vibration peak at 0deg model rotation, 60 deg inclination, no helical fillet, smooth flow (repeat of the 2008 tests)

provided similar large amplitude but started earlier and we had a wider peak. The tip of the peak coincided perfectly with the lower Cd value as pointed out from the 2008 data. However, this was true only for the 0 deg. case! At +2 or -2 or 54.7 or 90 deg, this was not the case! It seems that we had a new model for each model rotation with a different behavior. We broke 4 threaded rods in the last 2 weeks due to fatigue. We need to spend time now to analyze the data to look for similarities and find out what triggers the vibrations. There are several phenomena that co-exist making it very complicated to describe. I believe though that we made significant progress in the last two months of tests and we have a very comprehensive set of data to work with in addition to the experiments of the last 10 years.}

End of Comments

NRC staff is currently working on detailed analysis of the extensive test data and preparation of the summary report. This activity will be interrupted briefly by attendance of several key staff at the 13th International Conference on Wind Engineering (ICWE13) in Amsterdam, Netherlands during the period July 11-15, 2011.

Regarding another matter, a second draft version of the design guide has been reviewed and edited by one key member of the Expert Panel formed previously. We have held off on circulating this for some time now in hopes of filling in some of the areas where information is lacking. In the interest of moving things along, however, a decision will be made soon regarding when to circulate this new draft to the TAC for comments.