Structural Monitoring for the Huey P. Long Bridge Widening Project

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ABSTRACT
The Huey P. Long Bridge spans nearly 2,400 feet over the Mississippi River in New Orleans, Louisiana. This cantilevered steel through-truss bridge opened to traffic in 1935 and is owned and operated by the New Orleans Public Belt Railroad. The bridge currently carries dual rail lines between the trusses and two lanes of vehicular traffic cantilevered to the exterior of each truss. The Louisiana Department of Transportation and Development decided to widen the bridge rather than replace it, based on the need to improve vehicular traffic flow and constraints due to uninterruptible rail traffic.

The widening will entail the addition of upstream and downstream trusses parallel to the existing truss along with required modifications to the piers and will facilitate an additional traffic lane in each direction, widening of the traffic lanes, and dual shoulders in each direction. Construction under this four-phase project commenced in April 2006 and is expected to be completed in 2013.

Throughout the duration of the widening, the existing truss members will be monitored with an array of over 800 strain gages designed to measure axial and bending load effects. During construction, daily comparisons will be made between predicted and measured stress values to determine whether the erection is progressing as expected.
and to alert the construction team to any possible problems or necessary changes in procedure. This paper will provide specific results collected to date, including the baseline data and the behavior of the bridge during the load test conducted.

INTRODUCTION
The four main spans of the Huey P. Long Bridge extend nearly 2,400 feet over the Mississippi River in New Orleans, Louisiana. This cantilevered steel through-truss bridge opened to traffic in 1935 and is owned and operated by the New Orleans Public Belt Railroad. The bridge currently carries dual rail lines between the trusses and two lanes of vehicular traffic cantilevered to the exterior of each truss. Based on the need to improve vehicular traffic flow and constraints due to uninterruptible rail traffic, the Louisiana Department of Transportation and Development (LA DOTD) decided to widen the bridge rather than replace it. A structural health monitoring program is included in the construction contract as a proactive measure to assess whether the anticipated amount of load is being transferred from the widening truss members to the existing truss members.

Widening of the Huey P. Long Bridge is part of the TIMED (Transportation Infrastructure Model for Economic Development) Program, which was established in 1989. Through its support of transportation construction projects, the TIMED Program aims to improve economic development in Louisiana and is the largest transportation program in state history. The Program encompasses several transportation projects throughout the State of Louisiana including improvements to over 500 miles of state highways, widening or construction of three major bridges, and improvements to the Port of New
Orleans and New Orleans International Airport. A four cent-per-gallon tax on all gasoline and fuel is funding these projects and will continue throughout the duration of the TIMED projects and the payment of any bonds.

THE BRIDGE STRUCTURE

The main spans of the Huey P. Long Bridge are comprised of a three-span cantilevered truss with spans of 530 feet, 790 feet, and 530 feet and a through truss span of 530 feet as shown in Figure 1. The roadway sits approximately 135 feet above the Mississippi River. Over the river, the railway and vehicular portions of the bridge merge at the same elevation to form a combined structure. Away from the river, the railway and vehicular portions of the bridge split in elevation due primarily to the strict grade requirements of the railroad and adjacent vehicular intersection constraints.

Figure 1 – Huey P. Long Bridge Structure
The railway bridge structure is nearly 23,000 feet long and is the longest railroad bridge in the United States. The dual rail lines are supported between the trusses with the two lanes of vehicular traffic in each direction supported by cantilevered floorbeams outboard of each truss. The vehicular bridge structure is just over 8,000 feet long with steep grades on each end servicing about 50,000 vehicles daily, as well as carrying a dual-track rail line as shown in Figure 2.

Figure 2 – Dual Tracks between Trusses

The bridge widening will facilitate an increase in roadway width on each side of the bridge from its current width of 18 feet to 40 feet. This expansion will accommodate an additional traffic lane in each direction, widening of the traffic lanes, and the addition of dual shoulders in each direction. By increasing the width of the bridge roadways from
two 9-foot lanes in each direction to three 11-foot lanes with shoulders, officials expect to improve traffic flow in the area.

The widening will entail the addition of upstream and downstream trusses parallel to the existing truss along with required modifications to the piers. The bridge piers are being modified with additional concrete encasements and W-shaped steel frames to support the two new widening trusses that run parallel to the existing trusses as shown in Figure 3.

Figure 3 – Rendition of Bridge after Widening

PROJECT TEAM

Bridge Designer: The Huey P. Long Bridge was originally designed in 1931 by Modjeski, Masters, and Case, now Modjeski and Masters, Inc. who also designed the current widening of the bridge.
Bridge Owner: New Orleans Public Belt Railroad owns and operates the bridge.

Project Management: Louisiana TIMED Managers (LTM), representing LA DOTD, is serving as project manager for this and the other projects in the TIMED Program.

Construction Contractor: MTI, a joint venture between Massman Construction Co., Traylor Brothers Inc., and IHI Inc., was awarded the superstructure contract in August of 2007. HNTB is serving as the contractor’s engineer for erection and construction modeling of the structure. Part of the construction specifications included the requirement for truss monitoring (Bid Item S-107) during construction and through the completion of the project, scheduled for 2013.

Truss Monitoring Contractor: Under contract with MTI, CTLGroup was awarded the contract to design and install the truss monitoring system for the Huey P. Long Bridge. The field portion of the work for the truss monitoring system began at the end of January 2008.

**TRUSS MONITORING**

Bid Item S-107 Truss Monitoring consisted of the following:

1. Determination of initial dead load stresses in existing eyebar members
2. Installation of strain gages for measurement of dead load stresses in 433 members
3. Installation of strain gages for measurement of live load stresses in 31 members
4. Installation of biaxial tiltmeters on each of the five existing piers
5. Monitoring system to read the gages, make comparisons with predicted values, and provide daily reports throughout the construction process
6. Perform load testing to calibrate the monitoring system

The following sections describe the work involved for each of the above tasks.

**Existing Stress in Eyebar Members**

The Specification\(^{(1)}\) states “Determine initial dead load stresses in existing eyebar members marked on the plans for monitoring, based on their frequency of vibration using accelerometers or other approved methods.” There were a total of 12 eyebar locations (96 total eyebars) indicated on the plans for monitoring. These locations are marked with a red line in Figure 4. Each location consisted of a nest of six, eight, or ten eyebars. The top chord member consisting of ten eyebars in the nest is shown in Figure 5.
Figure 4 – Eyebar Nest Locations for Testing

Figure 5 – Ten Eyebar Nest in Top Chord with Accelerometer Noted
To determine the initial dead load stresses in each eyebar, CTLGroup used a magnetically-attached accelerometer (arrow in Figure 5) to measure the frequency of vibration of the eyebar under ambient conditions. Using linear averaging method, measurements were taken continuously over an approximately 10-minute period for each individual eyebar. All measurements were taken while the bridge was open to both rail and vehicular traffic. Data was collected in the time domain and post-processed in the frequency domain to ascertain the resonant, or natural, frequency of each eyebar as shown in the example in Figure 6.

Figure 6 – Sample Frequency Data
Collected data was processed using proprietary algorithms to determine existing forces in the eyebars. Predicted eyebar forces were provided by HNTB\(^{(2)}\). Table 1 presents averaged measured values for an eyebar nest and compares the measured and predicted axial force values. It should be noted that measured values are consistent for the same member location, i.e. both upstream and downstream truss readings and both UA1-UA0 and UA1'-UA0' locations, for example. Additionally, the measured values are generally higher than the predicted values, but are largely within an expected range of variation. During the construction project, additional force measurements of the eyebars may be required to confirm the measured response from the truss monitoring system.

### Table 1 - Comparison of Eyebar Forces, kips

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| Truss Monitoring System

A total of 433 existing truss members of the bridge are monitored with an array of 819 static and dynamic strain gages designed to measure axial and bending load effects.
Monitoring of the inclination of the piers in both the longitudinal and transverse directions is conducted with the use of tiltmeters. Table 2 shows the distribution of this sensor array relative to the member locations.

### Table 2 – Sensor Location and Count

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<tr>
<th>DESCRIPTION</th>
<th>STATIC GAGES</th>
<th>DYNAMIC GAGES</th>
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<td>Top and Bottom Lateral Bracing (Axial)</td>
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<td><strong>769</strong></td>
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</table>

**Sensor Installation**

The steel truss member types generally fall into the following categories: built-up box members, built-up I members, rolled I members, eyebars, and double angle members. Each member type has particular considerations for sensor installation. For example, on member faces that contain bolts or rivets, the sensors are installed between the bolts/rivets. Additionally, in an effort to avoid the effects of the connections on the measurements, each sensor was located no closer than two times the largest cross-section dimension of the member from the edge of a gusset plate. Due to the nature of the modifications to the existing trusses that are necessary for the widening, specific attention had to be paid to avoid installation of sensors or other system equipment in areas where future work would be required on a member.
The static strain gages were vibrating wire strain gages. The dynamic strain gages were full-bridge electrical resistance strain gages. Both the static and dynamic strain gages were installed using a strain gage spot welder. Typical installation is shown in Figure 7. The strain gages were covered following installation and the strain gage lead wires were routed to the track-side hand rails, secured, and run to data acquisition enclosures.

Figure 7 – Spot Welding Strain Gage to Steel Member

Data Acquisition System

The truss monitoring data acquisition system is comprised of two separate monitoring systems; a static monitoring system and a dynamic monitoring system. The static
monitoring system reads the vibrating wire strain gages and is capable of a monitoring frequency on the order of one reading per second. This system will be monitored continuously throughout the project duration. The static system utilizes twenty-three track-side mounted enclosures that contain 16- or 32-channel multiplexers. The multiplexers read the strain gages and transmit the data wirelessly to one of four data loggers mounted on the track-side handrail. These data loggers then transmit the data wirelessly to the MTI office trailer approximately ¼ mile from the bridge site. This system is on continuously and updates the data approximately once every ten minutes.

The dynamic monitoring system reads the electrical resistance strain gages and is capable of much higher monitoring frequency on the order of 1,000 readings per second. This system will be monitored on-demand, such as during the locomotive load testing, to be able to capture peak measurements under moving loads. The dynamic system utilizes eight track-side mounted enclosures that contain 8- or 16-channel acquisition units that are networked along the length of the bridge. The system transmits the data wirelessly to the MTI office trailer approximately ¼ mile from the bridge site. This system is on continuously, but only collects data when polled remotely.

The bridge rendition in Figure 8 shows the members instrumented on the downstream side of the bridge and the approximate locations of the data acquisition system enclosures. The central computer/server, which is located in the MTI office, collects, archives, and posts data to a website for password-protected remote access. This computer can also be remotely accessed for software changes.
**Data Processing**

For the static system, the strain gages are read, converted to axial and bending stresses for each instrumented member and posted in tabular form to the website. The current settings are such that the website is updated every ten minutes with current data. The basic layout for the web-based data reporting is shown in Figure 9. For the live load system, the strain gages can be polled remotely from the MTI office or elsewhere on demand.
Baseline Data

As part of the truss monitoring program, baseline data was collected prior to construction activities to provide for a reference during the monitoring period, as well as a measure of fluctuation in instrumented members under ambient conditions. A sample data plot illustrating these fluctuations is shown in Figure 10. The plot shows strain versus time and provides the results for five floorbeam gages; the gages readings are shown with 250 με separating their zero readings for ease of viewing the data. The baseline fluctuation ranges are different depending on the member type and location considered.
While baseline data was being collected and after system operation was verified, a load test was performed. This load test utilized a train locomotive of known weight placed at predetermined locations along the bridge. The load test provided a means for comparing the predicted response from HNTB’s model of the structure with the measured response and was the first of such comparisons that were made for the project. The results of the load test indicated that the structural response of the bridge was generally less than predicted. It was concluded that the HNTB model conservatively predicted the stresses considered due to additional structural load paths between the two planes of the truss.
Throughout Construction

Once construction activities begin, daily comparisons will be made between predicted and measured strain values to determine whether the erection is progressing as expected and to alert the construction team to any possible problems or necessary changes in procedure. Limits have been established on changes in strain on a member-by-member basis for each stage in the erection process. Comparisons will be made taking into account, baseline fluctuations, dead load (DL) and erection load (EL) effects. The truss member erection activities are scheduled to begin in August of 2009.

ACKNOWLEDGMENT

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REFERENCES


2. HNTB, Erection Engineers for the MTI Joint Venture.