Collaborative Research with The University of Memphis and the USGS; Downhole Seismic Instrumentation at the I-40 Mississippi River Bridge in Memphis, Tennessee

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The purpose of this project is to purchase and install two downhole triaxial sensors to complement a strong motion instrumentation system planned to be deployed on and in the vicinity of the I-40 Hernando DeSoto Mississippi River Bridge in Memphis, Tennessee. This bridge is being retrofitted to withstand a magnitude (m_b) 7 event at 65 km distance from the site at a depth of 20 km. The goal of the retrofit is to have this bridge fully operational following the maximum probable earthquake (2500 year return period). As part of the I-40 bridge retrofit, Friction Pendulum™ Isolation Bearings will be used to insure the integrity of the main spans of the bridge.

The I-40 bridge is scheduled to be retrofitted in several phases. Therefore, there is a window of opportunity to install an integrated system of seismic strong-motion instruments on and around the vicinity of the bridge during the retrofit construction phase. A strong-motion instrumentation with 114 data channels at 38 different locations on the bridge and 6 channels at two free-field sites in the vicinity of the bridge is proposed to be installed. This will provide needed data to better understand the ground motion and ground failure and the response of the retrofitted bridge in a strong earthquake. As the foundation is being retrofitted and expanded, there will be an excellent opportunity to install a downhole seismic sensor in each footing about 95 ft below the bottom of the existing river bed and about 130 ft below the high water level.

Two downhole systems have been purchased to complete the seismic instrumentation of the I-40 Bridge (see Figure 1). These downhole systems consist of a triaxial accelerometer and a triaxial broadband velocity seismometer with 2 channel inclinometer. The sensors will be installed on the pile caps in Pier C (Figure 2) and Pier 28 (Figure 3) and will record the foundation motion, including the effect of soil-structure interaction, in two horizontal directions and a vertical direction. An estimate of the soil-structure interaction effect may be obtained by comparing the motion recorded at the bridge foundation and in the free-field.

Triaxial Accelerometer portion
Eentec model EA-140 sensor
Force balance sensor design
Sensor Orientations: Vertical plus two orthogonal horizontal components
Cross Axis Sensitivity: .02G per G
Frequency Response: DC TO 50 Hz
Dynamic Range:140dB
Clip Level: +/- 2G
Power requirement +/- 12 VDC at 30 mA. maximum
Output Voltage: +/- 10VDC single ended for full scale
Dynamic self test Capability
Vibration Survival: 5G rms 20 – 2000Hz
Shock Survival:100G 11ms.

Triaxial Broadband velocity seismometer portion
PMD model 103 sensor
Sensor Orientations: Vertical plus two orthogonal horizontal components, Frequency Response: 0.05 to 5 Hz.
Sensor noise floor at 1 Hz –140 dB minimum (power spectral density), Clip Level +/- 10mm/sec
Output Voltage: +/- 7.5VDC differential for full scale
No remote mass centering or mass locking, Operable with base tilt to +/- 15 degrees, Power requirement + 12 VDC at 10 mA. maximum

Biaxial inclinometer

Range: +/- 25 degrees
Output voltage: 100mV per angular degree
Power requirements: + 12 VDC 10mA maximum

Figure 1. Custom shallow borehole packages incorporating triaxial broadband and accelerometer sensor components.

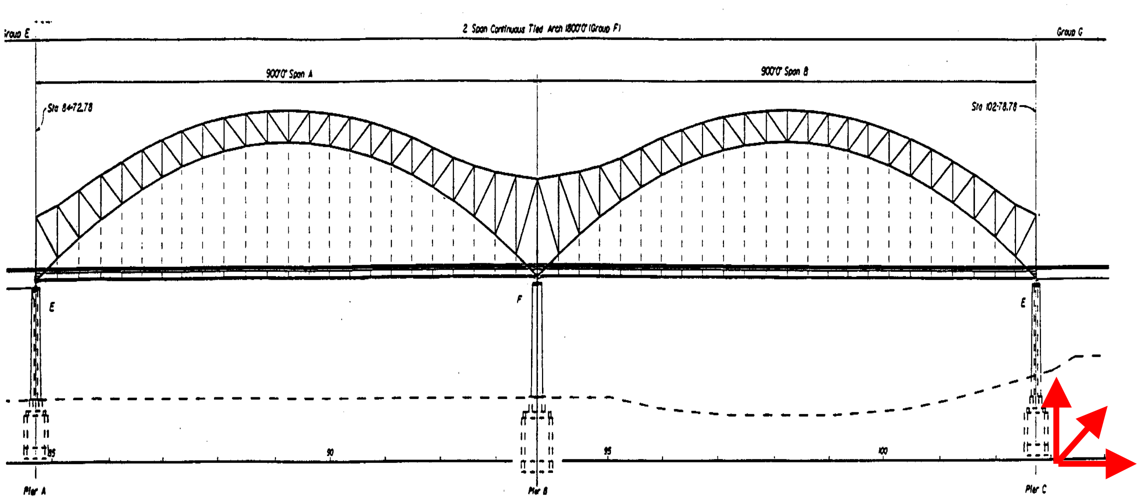

Figure 2. Downhole Sensor Location at Pier C.

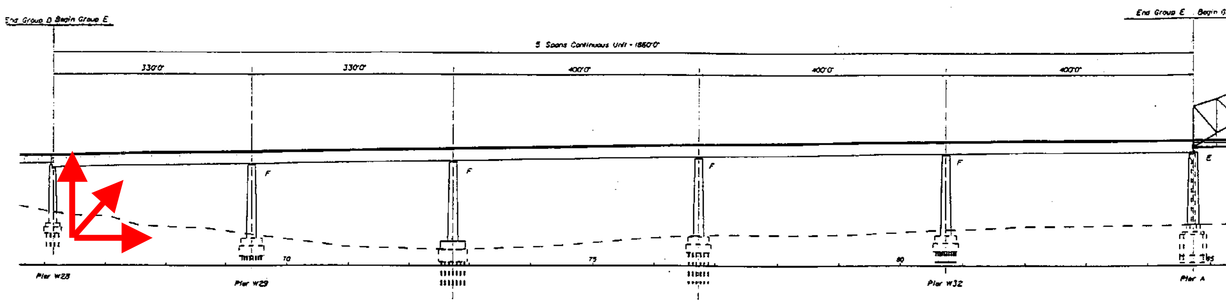

Figure 3. Sensor Location at Pier 28.

The free-field sensors will be installed and operated through funds from ANSS. The piping and conduits and their installation for the downhole instruments have been installed in Pier 28 and are being installed in Pier C.

The proposed I-40 bridge strong-motion instrumentation system with 114 data channels at 38 different locations will provide a sufficient number of sensors to reconstruct of the behavior of the structure in sufficient detail to verify the response predicted by mathematical models. Using data collected from smaller earthquakes an improved mathematical model of the bridge can be developed. Furthermore, a well-instrumented structure for which a complete set of recordings has been obtained, should provide useful information to:

(1) check the appropriateness of the dynamic model in the elastic range,
(2) determine the importance of nonlinear behavior on the overall and local response of the structure,
(3) follow the spreading nonlinear behavior throughout the structure as the response increases and determine the effect of this nonlinear behavior on the frequency and damping,
(4) correlate the damage with inelastic behavior models,
(5) determine the ground-motion parameters that correlate well with bridge response and/or damage,
(6) quantify the interaction of soil and structure (this is particularly important for the I-40 bridge which is located on 3000 feet of soil), and
(7) make recommendations to improve seismic codes and/or future bridge designs.

An improved model of the I-40 bridge can be used to predict potential damage/failure that the structure may experience during large seismic events. An accurate bridge model will be a cost-effective approach in evaluating the retrofit scheme, investigating ways to improve bridge performance, and reducing the possibility of catastrophic failure during a large seismic event.