SEISMIC VIBRATION MONITORING AT RAMP CONSTRUCTION NEAR THE MARTIN LUTHER KING BRIDGE, EAST SAINT LOUIS, ILLINOIS

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ABSTRACT

The Illinois Department of Transportation is constructing new collector/feeder ramps for the Martin Luther King Bridge over the Mississippi River in East St. Louis, Illinois. The design of the new ramp over Interstate 70 required construction of two support piers adjacent to the north and south shoulders of the highway. The pier caps are founded on driven pile, bearing on limestone, over 80 feet below ground surface. Construction of the ramps was complicated by the existence of two, 9-foot diameter reinforced concrete pipe (RCP) storm sewers running parallel to the two northernmost outer lanes, directly below the highway. The pile cap required the installation of vibrated sheet pile shoring and driven H-pile within 4 feet of the outside wall of one of the sewers. Collapse of the rehabilitated sewer would close this busy section of Interstate 70. Illinois Department of Transportation engineers required that seismic peak particle velocities be lower than the 1986 Bureau of Mines vibration threshold of 2.0 inches per second. Vibration monitoring was conducted in August and October 1999 throughout the pile installation process for both sides of the interstate. The seismic waves were recorded using three-component geophones mounted on the shoulder of the interstate and in a borehole at a depth representative of the level of the sewer pipes. The sewer pipes were visually inspected when peak particle velocities approached or exceeded the 2.0 inch per second threshold, and damage was not observed as a result of the pile driving activities.

INTRODUCTION

The Illinois Department of Transportation is constructing new collector/feeder ramps for the Martin Luther King Bridge over the Mississippi River in East St. Louis, Illinois. The design of the new ramp over Interstate 70 required construction of two support piers adjacent to the north and south shoulders of the highway. Construction of the ramps was complicated by the existence of two nine-foot diameter reinforced concrete pipe (RCP) storm sewers running parallel to the two northernmost outer lanes directly below the highway (Figure 1). The pile cap required the installation of vibrated sheet pile shoring and driven H-piles within four feet of the outside wall of one of the sewers. Highway engineers were concerned that excessive vibrations could potentially crack the RCP sewer causing a catastrophic collapse of the interstate. The Illinois Department of Transportation required that seismic peak particle velocities be lower than the 1986 Bureau of Mines vibration threshold of 2.0 inches per second. Vibration monitoring was conducted in August and October 1999 throughout the pile installation process for both sides of the interstate.

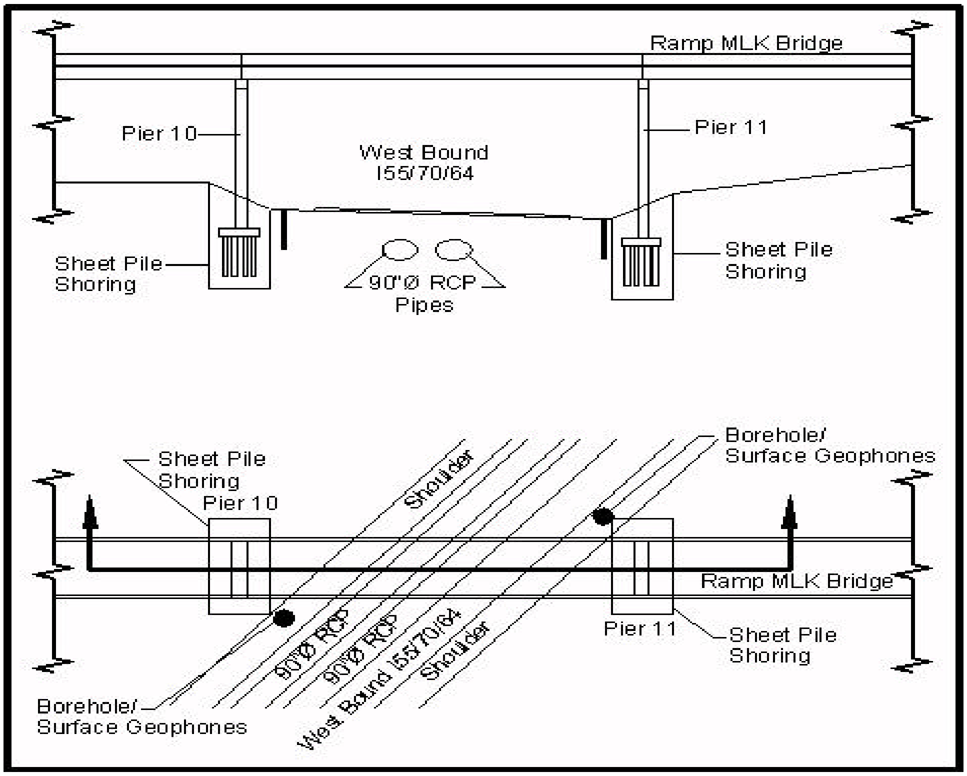

Figure 1. Layout of the pier and sewer locations.

GEOLOGIC BACKGROUND

Unconsolidated sediment at the site consists of the Cahokia Alluvium, a recent alluvial deposit of the floodplain, typically consisting of layers of clay and silt with some fine sand (Willman, et. al., 1975). The Cahokia Alluvium attains a thickness of up to 75 feet in the study area. The Cahokia Alluvium overlies the Wisconsinan-aged glacial sands and gravels of the Henry Formation (Willman, et. al., 1975).

The stratigraphic succession of the survey area in East St. Louis consists of approximately 80-100 feet of alluvial sediments situated over the Mississippian Salem and St. Louis Limestones (Figure 2).

The Salem Formation is comprised of cross-stratified, fossiliferous limestone and dolomite (Thompson, 1995). A “cannonball” chert zone is located near the top of the formation and indicates the contact between the Salem Formation and St. Louis Limestone. The formation ranges between 100- and 160-feet thick and becomes more dolomitic in the St. Louis area. Several types of fossils are found in the formation including blastoids, crinoids, echinoids, and bryozoan (Thompson, 1995).

The St. Louis Limestone is comprised of fine to medium grained, medium- to massive-bedded limestone and dolomite (Thompson, 1995). Shale partings commonly occur between beds. The thickness of the St. Louis Limestone is generally less than 50-feet in the St. Louis area.

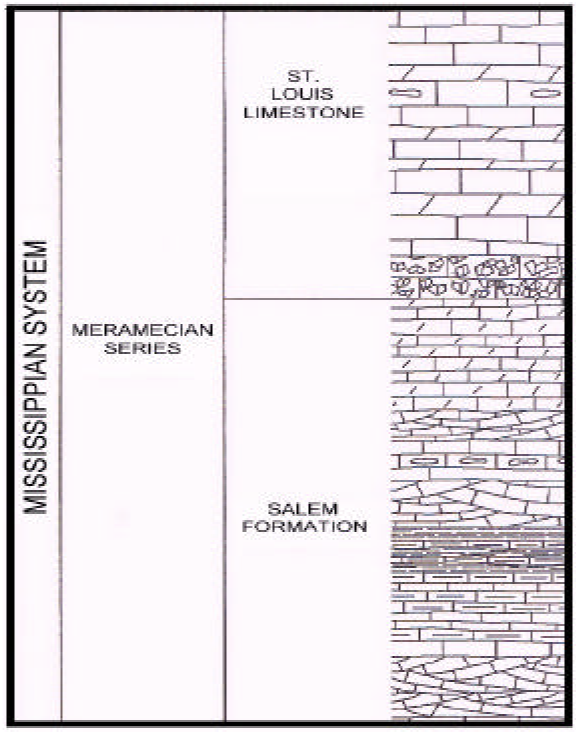

Figure 2. Generalized stratigraphic column for the study area.

VIBRATION MONITORING

Vibration monitoring was conducted at the site during sheet pile driving and H-pile driving. In order to determine the appropriate seismograph trigger levels, background vibrations were recorded during a period when construction activities were not taking place. Due to the proximity of the geophones to the highway, a trigger level of 0.45 inches per second was selected.

Two 10-foot deep boreholes were installed on the shoulder of the highway adjacent to the pier caps. The boreholes consisted of 6-inch full length, open ended PVC casing. The borehole depths were approximately the depth of the centerline of the sewers. Geophones were placed at the ground surface and at the base of the borehole between the pile cap and sewers.

Two White Industrial Seismology Alpha-Seismite seismographs were used to record the vibrations from pile-driving activities. The seismograph system consisted of a three component geophone with a frequency response of 2 to 250 Hz. Once triggered, the seismographs were programmed to record vibrations for 4.5 seconds.

Temporary shoring for the pile caps consisted of 30- to 40- foot long PZ-27 sheet piles, vibrated into place. Permanent HP14X89 piles were vibrated to within 5 to 10 feet of bedrock, then driven to refusal with a Delmag D19-32 diesel hammer, operating at 28,680 ft-lbs.

The Alpha Seismite seismograph was adjusted each day to monitor a general representation of the highest peak particle velocities (PPV). Each of the recorded events was plotted on the United States Bureau of Mines (USBM) limits graph for radial, vertical and transverse components of particle motion (Siskind *et al*, 1980). The peak particle velocity is the instantaneous maximum velocity recorded for an individual event. The seismic record could also be analyzed for frequency content by using a fast Fourier Transform. A typical vibration record with corresponding USBM curves and frequency spectra is presented in Figure 3.

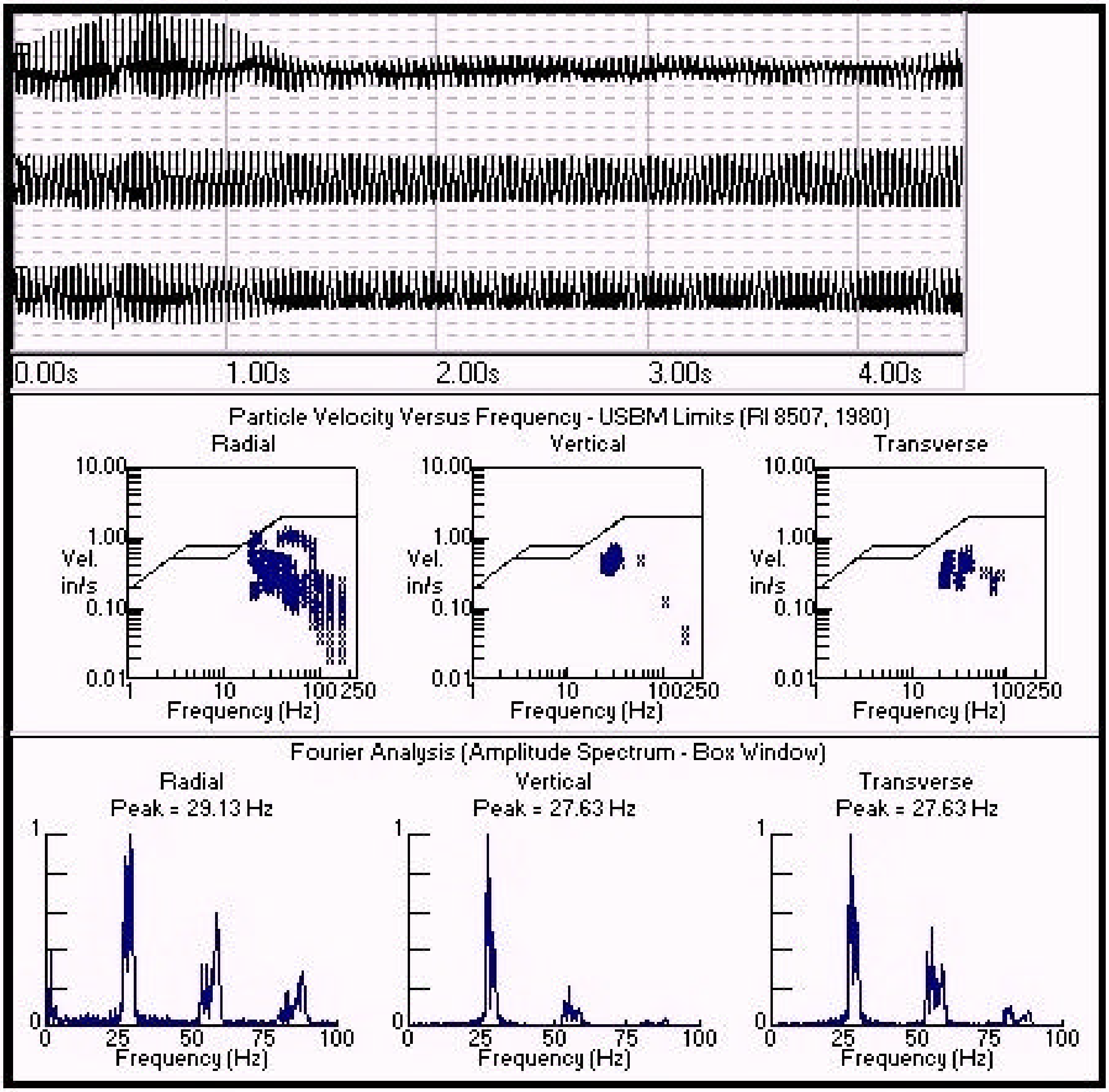

Figure 3. Typical vibration record with USBM curves and frequency spectra.

Temporary sheet piles were driven on the west abutment/Pier 10 on August 12, 13 and 16, 1999. The maximum recorded PPV occurred on August 16 at the sheet location closest to the geophones. The maximum velocity recorded was at the surface geophone at 2.12 inches per second. A maximum particle velocity of 1.76 ips was recorded at the downhole geophone on August 16.

Installation of temporary sheet piles at the east abutment/Pier 11 started on October 18, 1999. The maximum velocity recorded during installation of sheet pile at Pier 11 was 1.36 inches per second in the downhole geophone. A maximum particle velocity of 0.79 ips was recorded at the surface geophone on October 18. Vibrations were monitored on approximately half of the sheet installations, including the sheets closest to the monitoring point. IDOT engineers elected to forgo additional monitoring because of the relatively low PPVs.

Permanent H-piles were driven for pier 10 on August 24 and 25, 1999. The maximum recorded PPV occurred on August 24, at the pile location closest to the geophones. The maximum velocity recorded was 0.56 inches per second in the downhole geophone during installation of Pile 18. Vibration monitoring for H-pile installation at pier 11 was not requested by IDOT engineers because of the relatively low PPVs recorded during the sheet pile installation.

DISCUSSION

Maximum peak particle velocities were observed during vibratory sheet pile driving close to the geophones. Maximum particle velocities of 2.12 and 1.76 ips were recorded on August 16, 1999 at the surface and borehole geophones, respectively. The dominant frequency of the seismic waves recorded in the borehole during the maximum event was 30 Hz. Seismic waves recorded in the X-Y direction were larger than the Z direction in the borehole. The dominant frequency of the seismic waves recorded at the surface during the maximum event was 12 Hz. Seismic waves recorded in the Z direction had a larger amplitude than the X-Y direction on the surface.

The larger amplitude vertical component recorded by the surface geophone is the result of low frequency ground roll. Seismic waves recorded during sheet pile driving were significantly higher in amplitude and velocity compared to waves recorded during H-pile driving. The H-piles were driven within the shored excavation, which was 20 feet below the surrounding surface elevation. The driven sheet piles combined with the increased depth of the excavation acted as a “barrier” to the impending seismic energy. Furthermore, the sheet piles have a larger surface area compared to the H-piles. This increased surface area produced a larger amount of skin friction against the soil, resulting in higher amplitude vibrations.

SUMMARY

Seismic vibration monitoring was conducted near the construction of new collector/feeder ramps for the Martin Luther King Bridge in East St. Louis. The peak particle velocity threshold of 2 inches per second was exceeded in only one of the 307 recorded vibration events. According to verbal reports from IDOT engineers on site, no damage to the sewers was observed during construction of Piers 10 and 11.

REFERENCES

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