Modeling Seismic Response for Highway Bridges in the St. Louis Area for Magnitude 6.0 to 6.8 Earthquakes

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ABSTRACT

Two highway bridges spanning the Missouri River flood plain were selected for evaluation of seismic site response for the most probable earthquakes we can expect to see in the near future emanating from the three principal sources in the Midwest: the New Madrid Seismic Zone; Wabash Valley Seismic Zone; and Southern Illinois Seismic Zone. This study focused on the expected range of earthquakes magnitudes: M 6.0, 6.3, 6.5 and 6.8. These have a 25 to 40% probability of occurring over the next 50 years. Most previous efforts have focused on M 7 to 7.6 quakes, such as occurred in 1811-12. The 1811-12 quakes only have a 7 to 10% probability of occurrence in the next 50 years.

Our results suggest site amplification between 550% and 950%, depending on earthquake magnitude and epicentral distance. Our study suggests that the threshold magnitude for significant foundation failure and structural damage to Missouri River bridges is between M 6.4 and 6.6. Above these magnitudes widespread liquefaction is predicted, which would dampen ground acceleration, but would sever foundation elements, such as piles or caissons. Site amplification could be expected where the site period is > 1.0 second (s). Therefore, M 6.5+ earthquakes at ranges 110–260 km could cause severe damage to structures 10 to 25 stories high founded on channel deposits with > 30 to 46 m of unconsolidated sediment.

The geology of the Missouri River floodplain is typified by bedrock bluffs and channel floors developed in dense Paleozoic limestone and dolomite, covered by glacial windblown silt (loess). The channel flood plain is filled with young unconsolidated sands and silt. The upper 2 to 4 meters of the flood plain are usually covered with recent lake sediments and overbank floodplain silts and clays. The thickness of the channel fill varies between 30 and 60 m.
Earthquake source and wave propagation were characterized using SMSIM code of Boore (1993), from the US Geological Survey. Site Response is characterized using DEEPSOIL v.2.5, from the Univ. of Illinois.

Response Spectra
The site response at the ground surface is markedly different from the base rock input motion and site response increases as the magnitude increases:
CONCLUSIONS

1. Preliminary results indicate that the bridges we analyzed would be subjected to long period motions, which may pose a significant threat to simply-supported tail spans founded on friction piles.

2. Large amplifications can be expected at both bridge sites. Amplification of the ground motion is in the range of 550% to 950%.

3. Similar site amplification was predicted for earthquakes at distances of 110 to 210 km, because there is only slight attenuation of seismic energy in the stiff Paleozoic bedrock.

4. Widespread liquefaction is predicted at the Creve Coeur Bridge site for ≥ M 6.8 event, but only localized liquefaction for M 6.3-M 6.7 events.

5. The screening analysis did not predict any liquefaction at the Hermann Bridge site.

6. Soil softening (liquefaction) may cause a decrease in response spectra values for periods < 1 sec.

7. However, soil softening may cause an increase in response spectra values for periods >1 sec.