MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 24-517 (project 694) | March 2024

Calibrating Ground Response Analyses Beneath an Instrumented Bridge using the I-15 Borehole Array and Ground Motions from the 2020 M5.7 Magna Earthquake

the ISSUE

Engineers need improved predictive models that better approximate seismic forces so they can design transportation infrastructure to be resilient against large earthquakes.

the RESEARCH

In 2020, a magnitude 5.7 earthquake struck near Salt Lake City, Utah. This earthquake was recorded by a unique arrangement of seismometers, called a downhole array, at the intersection of I-15 and I-80. This seismometer array is known as the I-15 Downhole Array (I15DA). While the instrumentation failed to record the main shock of the earthquake, it recorded several aftershocks. These aftershocks were used to help calibrate numerical ground response analyses aimed at predicting the site-specific amplification of seismic waves as they traveled out of bedrock and up through the soft soils beneath the I15DA. This was done by calculating empirical transfer functions (ETFs) between the deepest sensor in the array and the ground surface for each recorded aftershock. These ETFs were then compared to theoretical transfer functions (TTFs) that were developed from analytical and numerical methods. The goodness-of-fit between the ETFs and TTFs were evaluated and modifications to the modeling efforts were made in attempts to improve the TTFs. In particular, attempts were made to reduce the amplitudes of TTFs by incorporating spatial variability into the modeling approaches.

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Lead Investigator(s)

Brady R. Cox, Ph.D., P.E.
brady.cox@usu.edu

Research Assistant(s)

Tyler Jackson, GRA, BS
Nishkarsha Dawadi, GRA, MS

Project Title

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the FINDINGS

It was found that typical one-dimensional (1D) ground response analyses based on a single shear wave velocity profile significantly over-estimated amplification of seismic waves at the I15DA relative to the actual recorded aftershocks. Therefore, attempts were made to incorporate the effects of spatial variability into 1D and 2D ground response analyses using several approaches. While efforts to incorporate spatial variability helped to reduce over-estimation of amplification and improve the agreement between recorded ground motions and predictions, some over-amplification was persistent, particularly at the fundamental mode of the site. This problem has been noted at other borehole array sites around the world, and figuring out how to better model site response is an active research topic. The data gathered and analyses performed at the I15DA will contribute greatly to these future studies, as it is now one of the best-characterized downhole array sites in the world.

the IMPACT

Large earthquakes have historically caused significant damage to transportation infrastructure. Thus, engineers must use predictive models to account for potential seismic forces in infrastructure design. This research illustrates that our models for predicting seismic ground response still need to be improved, such that design of our transportation infrastructure is performed in a safe and economically efficient manner. This research aims to improve future seismic design methods and will ultimately benefit society by improving our abilities to better predict seismic forces.

For more information on this project, download the Main report at https://www.ugpti.org/resources/reports/details.php?id=1163

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.