EXPERTS TALK

Seismic Resiliency in Bridge Design with Kuang Lim

Using seismic analysis in bridge design and retrofits can create safer, more sustainable structures at similar construction costs.

Most people who live in North America are familiar with the parts of the country that have the highest occurrence of and potential for earthquakes. In addition to California, Oregon, Washington State and the Pacific Islands, scientists have identified southern and Midwestern states that also have the potential for seismic activity. Even more recently, substantial scientific data shows increased potential for earthquakes in areas where oil and natural gas are produced. For these reasons, seismic analysis will be required in more and more bridge engineering and construction projects to withstand such events.

Kuang Lim, Ph.D., P.E., helps lead our Bridges & Structures practice in California. Originally from Malaysia, he received his bachelor's and master's degrees in civil engineering from Texas Tech University and his doctorate in structural engineering from Washington State University. He is a licensed professional engineer in three states. Kuang is recognized for expertise in structural analysis, and seismic design techniques and standards. His doctoral research focused on enhancing the strength and ductility of concrete bridge substructures under seismic loading. He has served as project engineer and project manager for seismic retrofits of simple-span to long-span bridges. His research has helped develop design guidelines for nonlinear behavior of steel and concrete structures for the seismic retrofit design of the Golden Gate and Richmond-San Rafael bridges. And in 2007, his role as project manager helped the Golden Gate Bridge Phase II Seismic Retrofit Project win the Outstanding Civil Engineering Achievement from the American Society of Civil Engineers. Contact **Kuang Lim** for more information on seismic resiliency in bridge design.

Q. Most people in North America are aware of earthquake prone regions, especially the West Coast. Should seismic resiliency be a consideration only in these areas? Why or why not?

A. Regions with low or no seismic activity should not be exempted from earthquake-resilience considerations because earthquakes can occur anywhere. Although seismic hazards are greatest in California, Washington and Oregon, as well as Alaska and Hawaii, the U.S. Geological Survey has identified earthquake potential in portions of several southern and Midwestern states. There is also growing concern about earthquakes induced by activities associated with oil and natural gas production, which is taking place in many regions of North America.

Q. Regardless of location, what types of bridge designs merit the most attention to seismic resiliency?

A. All bridges have oscillation rates at which they will move back and forth if given a horizontal push. This oscillation rate is known to structural engineers as a bridge's natural period. Earthquakes create inertial forces within a bridge's structure and the bridge's natural period will determine how much the bridge responds to these forces.

Inertial force equals mass multiplied by acceleration. Consequently, short, stiff and heavy bridges with short natural periods will attract larger inertial/seismic forces — such as stocky box girder bridges. Long-span, tall and flexible bridges such as cable-stayed and suspension bridges tend to have longer natural periods resulting in lower acceleration and thus, will attract lower seismic forces.

Q. What is resilience-based earthquake bridge design, and why is it necessary?

A. Resilience-based earthquake engineering is an interdisciplinary branch of engineering that accounts for potential seismic hazards. It uses a seismic hazard analysis to determine earthquake energy inputs for the purpose of bridge design. Seismic hazard analysis is not a straightforward task. It involves quantitative estimation of ground-shaking hazards at a particular site. Engineering judgment must be applied to the interpretation of the results. It requires experience and expertise from many professionals, including, at a minimum, a geologist, seismologist, geotechnical engineer and a structural engineer. It also requires risk analysis and input from other technical fields, as well as weighing social, economic, and political factors.

The "why it is necessary" can be answered by history. Bridges rarely experience complete failure during non-extreme events but when extreme seismic forces do occur, history has shown us that the results can be catastrophic. Bridge failures can result in the disruption of commerce, require costly repairs or worse — the loss of life.

Q. How have codes governing bridge design evolved to account for seismic activity?

A. The state of practice of bridge seismic design is continually evolving. Many design code updates during the last 50 years have resulted from observations of earthquake damages around the world. They often have provisions that prescribe "detailing" requirements such that certain structural systems must be configured in specific ways to provide ductility. Our scientific understanding of the phenomena that produce earthquakes continues to evolve and inform what we know about earthquake-induced ground motion. Codes are developed to take into account the significance of site conditions on the amplification of ground motion, improvement in the detailing practice, and the ability of structures to withstand certain types of damages and continue to remain standing.

Q. How does an earthquake resilience-based design impact the life-cycle costs of a bridge, including operations and maintenance costs?

A. Depending on the schemes used in the seismic design, the construction cost premiums and life-cycle costs associated with meeting current seismic standards might not be a key factor. A properly engineered bridge structure does not necessarily have to be expensive.

In some regions, the lateral strength required for seismic design of the bridge is less than that required for code-specified wind design. In such cases, the design strength is not reduced, i.e., wind load cases governed the minimum design strength for these bridges, thus, there is no added cost to seismic design.

Today, seismic isolation and energy dissipation devices can be used as methods to mitigate earthquake hazards for designing new bridges or retrofitting existing ones. This concept has matured into a practical reality and is taking its place as a viable alternative to conventional (monolithic and fixed-base) seismic resilient construction. These seismic devices are relatively inexpensive, able to perform in extreme environments, reliable and durable. They require little maintenance. Isolation devices will reduce the seismic load input to the structure. The response of the structure is therefore in principle lower than it would be on a non-isolated bridge and allows smaller member sizes, resulting in lower initial construction cost.

Inspiration & Advice

Q. What inspired you to become a bridge engineer?

A. When I was in high school, my hometown, Georgetown in Penang, Malaysia, underwent rapid urbanization during the 1970s and 1980s. I was fascinated with the construction of high-rise buildings and the 8.4-mile cable-stayed Penang Bridge. Somewhere in my mind then there was always a wish to become a civil engineer.

Later, as part of my doctoral research, I conducted substantial experimental work on enhancing the strength and ductility of concrete bridge substructures under seismic loading. That research work led me down the path of becoming a bridge engineer.

Q. What advice do you have for bridge designers who are new to the profession?

A. College gives us the basic engineering tools. Understand and learn the basic engineering principles well. Thorough understanding of fundamental engineering principles is essential to practical application. Your understanding is also critical for problem solving in analysis and design. Don't be afraid to ask questions or request help when needed. And take responsibility for your own actions as you are responsible for your career. Do your work right the first time; don't count on a quality assurance and quality control process to fix your mistakes. Be a team player. The most successful projects are done by teams. Lastly, take the initiative and seek opportunities to learn and develop both technical and non-technical skills to assist project delivery.

Experts Talk is an interview series with technical leaders from across our Transportation program. Each interview illuminates a different aspect of transportation infrastructure planning, design and delivery. Contact HDRTransportation@hdrinc.com for more information. ***Visit www.hdrinc.com/insights regularly to gain insights from specialized experts and thought leaders behind our award-winning, full service consulting practice.***