Caltrans

DRISI
Caltrans Division of Research, Innovation and System Information

Geotechnical and Geohazards Research Roadmap

Goal

Support the implementation of a risk-management strategy for geologically-based hazards by developing models and engineering tools that enable risk-related decision-making, including the consideration of event likelihood, potential impacts, and focused mitigation.

Ground-Shaking Hazard

Ground Motion Prediction Equations (GMPEs) are used extensively in engineering design to characterize the potential severity of shaking that California is subject to. These statistical models must be updated periodically to reflect recent earthquakes and seismological knowledge.

Develop improved GMPE for subduction earthquakes

Challenge: In 2014 GMPEs were updated for shallow crustal earthquakes, but not for subduction activity. In northwestern California, seismic hazard is dominated by the Cascadia subduction zone. Current GMPEs for subduction earthquakes are relatively old and give inconsistent predictions.

Task: Develop a database of earthquake motion and fault properties from subduction events. This data will be used by different ground motion modeling teams to develop several new GMPEs applicable to subduction earthquakes.

Time frame: 7/1/2015 – 9/30/2017

Develop and implement a directivity model for shallow crustal GMPEs

Challenge: For sites within approximately 15 km of a rupturing fault, ground motion can be strongly influenced by the propagation direction of fault rupture. In cases where a rupture propagates toward a site, waves can constructively combine to create a large and potentially damaging wave pulse.

Task: Develop an empirically based model for directivity, using parameterizations driven by seismological theory. This model will be implemented in a seismic hazard computer program so that the hazard from such events can be practically evaluated.

Time frame: 7/1/14 – 5/30/17

Synthetic near-fault ground motion generator

Challenge: Near-fault earthquake records have unique time-domain properties that can strongly impact structural response. Since there are too few historical recordings from near-fault sites to capture the full range of properties one should consider for structural design, a method to generate synthetic near-fault records is needed.

Task: An initial model was completed in 2014. A follow-on project will make some improvements on the initial model, making use of these synthetic records more suitable for nonlinear structural analysis.

Timeframe: 2/1/16 – 1/31/17

Tsunami Hazard

California's coastline is vulnerable to tsunamis generated by distant Pacific earthquakes, primarily from Chile and the Aleutian Islands, and from a large event on the Cascadia subduction zone. Caltrans has about 40 highway bridges that are potentially impacted by tsunami waves. City and county jurisdictions have several hundred impacted bridges.

Tsunami hazard maps for the California coastline

Challenge: Current tsunami maps are based on maximum credible scenarios, many of which are very unlikely to occur. Maps of maximum wave height and inundation for varying levels of hazard are needed.

Task: Develop a tsunami hazard map at 10-meter resolution for engineering application. Also develop a simplified means for modeling on-shore sea wave propagation. TPF 5(307)

Time frame: 6/1/2015 – 6/1/2017

Bridge loading due to tsunami impact

Challenge: Provide data to assess the accuracy of current load prediction equations.

Task: Develop a simplified design methodology for estimating the force demands on bridge structures of various dimensions, structural systems, and orientations to the incident sea wave. TPF 5(307)

Time frame: 5/1/2016 – 6/1/2018

Landslide Hazard

California has over 1,600 miles of landslide-prone highway corridors that routinely cost the state over $40 million annually for repair and reconstruction. Beyond immediate safety implications, impacts of landslides include road closures, traffic delays, economic losses, and environmental degradation. Landslide hazard often is narrowly focused on recently-active slides, which tend to be only minor elements within a much broader context of geologic instability. A comprehensive resource of landslide-hazard data along with a convenient means to discover and display these data is needed to proactively manage landslide risks.

Landslide inventory maps for landslide-prone highway corridors

Challenge: A long-term multi-phase program of landslide mapping was initiated with the California Geologic Survey (CGS) in 1999. Phase 1, completed in 2006, yielded new methods, maps, and reports for 190 miles of Caltrans highway corridor, which have served as a resource for major projects such as the Route 1 Big Sur Coast Highway Management Plan, the Route 101 Confusion Hill realignment, and the current Route 101 Last Chance Grade realignment.

Task: Phase 2, now active, will extend the inventory mapping by approximately 280 miles, largely by leveraging existing CGS data resources for Los Angeles and San Francisco areas compiled under the Seismic Hazards Mapping Act of 1990. Phase 2 will also deliver a range of digital products for all 470 miles mapped under both phases in order to improve accessibility and utility of this information resource.

Time frame: 6/1/2011 – 6/30/2016 (Phase-2 only)

Liquefaction Hazard

Many of Caltrans' bridges have foundations that extend through soils that are expected to undergo liquefaction, i.e., dramatic strength loss during an earthquake. Liquefaction has been responsible for significant bridge damage in past earthquakes.

Improve models for the triggering of liquefaction

Challenge: Current models can give inconsistent predictions, particularly at very shallow and very deep depths.

Task: Develop improved models for predicting when liquefaction will occur within a soil profile. Other issues include the use of peak ground acceleration (PGA) as an intensity measure or more robust intensity measures such as CAV5.

Time frame: 2/1/2016 – 8/31/2018

Improved lateral spreading displacement estimation

Challenge: The primary cause of bridge damage resulting from liquefaction is ground displacement pushing into bridge foundations and abutments. The level of damage caused by lateral spreading is strongly dependent on the amount of displacement. Accurate predictions of displacement are illusive because the amount of displacement is dependent on a complex interaction of soil and bridge structure.

Task: In partnership with other funding agencies, collect lateral spreading case-history information from recent large earthquakes in Japan, New Zealand, and Chile. This data will be used to develop improved lateral-spreading prediction procedures for design.

Time frame: 2/1/2016 – 8/31/2018

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ShakeCast

Immediately after an earthquake, Caltrans emergency managers need to understand field conditions to coordinate the response and to dispatch infrastructure-inspection resources. Since 2008, Caltrans has used the ShakeCast alerting system to provide early situational awareness to emergency managers. ShakeCast combines data from ShakeMap, the U.S. Geological Survey's near–real time ground-shaking map system, and pre-calculated fragility relationships for Caltrans facilities such as bridges, buildings, and roads, to rapidly estimate the earthquake damage. ShakeCast automatically retrieves ShakeMap data, analyzes it against users' facilities, sends notifications of potential impacts, and generates maps and other web-based products for emergency managers. ShakeCast is particularly suitable for earthquake planning and response purposes by DOTs.

ShakeCast, Connecting the DOTs

Challenge: Caltrans has been working with the USGS over the last ten years to develop a robust and operational ShakeCast platform. A long-term goal is to "connect the DOTs"—to bring this technology to all states with seismic hazards, as anticipated major earthquakes will cross state borders.

Task: Bring participating DOTs into full ShakeCast operation. The recently released ShakeCast V3 system includes:

- A full statistical fragility analysis framework for general structural assessment of bridges as part of the near real-time system
- Significant improvements in the graphical user interface, including a console view for operations centers
- Custom, user-defined hazard and loss modules.
- Advancements in estimating the likelihood of shaking-induced secondary hazards to bridges and along roadways due to landslides and liquefaction.

Time frame: Completed

Seismic Bridge Fragility

The ShakeCast situational awareness system (see #2) requires bridge fragility relationships to estimate bridge damage from earthquake-specific ground motions. ShakeCast currently uses first-generation fragility models, which have several limitations that affect their usefulness for Caltrans' emergency response and planning applications. Most importantly, they do not address substantial variations in bridge performance associated with California's full range of bridge types, configurations, and design eras. In addition, they provide neither damage locations nor engineering metrics needed for quantitative estimation of repair needs. A new generation of more accurate and more useful bridge fragility relationships tailored to California's bridge inventory are being developed—primarily for incorporation into ShakeCast, and also to support seismic reliability evaluations of the state's bridge inventory.

Generation-2 Bridge Fragility Relationships, Phase 2 – Development of Production Models for Concrete Bridges

Challenge: This is Phase 2 of a multi-phase project that builds upon the knowledge and experience gained through a prototype end-to-end application of the methodology completed under the Phase I feasibility studies. The goal of Phase 2 is to develop and optimize a set of generation-2 fragility models for most concrete bridge classes in California, representing 80% of the inventory.

Task: Internal work at Caltrans characterizing California's bridge inventory for both class and model specification is being coordinated with contract work focused on advanced analytical modeling.

Time frame: 8/1/2013 – 11/30/2016 (anticipated extension to 6/30/2018)

Cost-Efficient and Reliable Bridge Foundations

Bridge foundations typically represent 30% of a bridge's overall cost. Problems with foundation construction are one of the most common causes of construction delay and cost escalation. Because of the uncertain nature of foundation capacity estimates, to ensure reliable performance, designers must make conservative assumptions, resulting in larger and more expensive foundations than might correctly be required.

Calibration of load resistance and factor design (LRFD) resistance factors for driven piles and cast-in-place piles

Challenge: Current resistance factors are based on a simple back-calculation to previous allowable stress-based factor of safety. Missing is consideration of different levels of capacity verification techniques and design procedures.

Task: This project is developing a pile load-test database that is then being used to perform a reliability analysis to calculate updated resistance factors as well as validate design procedures.

Time frame: 8/1/2014 – 6/30/2016

Reusable instrument test pile (RTP) development

Challenge: A system is needed to estimate pile capacity in difficult-to-characterize soils such as gravels and cobbles. The system also will act as an economical alternative to expensive conventional pile load tests.

Task: Develop an instrumented Becker hammer pipe string that can be used to measure dynamic resistance while driving. The test pile can also be statically tested in uplift.

Time frame: 4/1/2013 – 3/31/2016

Seismic Performance of Earth-Retaining Walls

Caltrans is one of the largest owners of earth-retaining walls in the world. Since most Caltrans facilities must be designed to withstand high levels of earthquake shaking, seismic design considerations have a large impact on cost.

Near full-scale shake-table testing of MSE walls

Challenge: Current design practices use an equivalent static seismic force approach that is generally considered to be very conservative. Wall costs can be reduced by using more accurate design procedures and focus on wall displacement instead of peak forces.

Task: Develop improved MSE wall-design procedures based on controlled shake-table testing. This testing allows careful measurement of input loading and force distributions within reinforcement. Due to the high cost of shake-table testing, a pooled fund project was created to find supplemental funding to NSF-supported projects. TPF 5(276)

Time frame: 2/1/2011 – 6/30/2018

For more information: