ShakeCast

Caltrans Deploys a Tool for Rapid Postearthquake Response

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After a major earthquake, one of the most critical tasks for the California Department of Transportation (Caltrans) is to assess the impact on the condition of all bridges and roadway corridors in the state highway system. Timely response ensures public safety, guides emergency vehicle traffic, and reestablishes critical lifeline routes.

Problem

Immediately after an earthquake, bridge inspection teams had difficulty setting priorities, because precise information was not available to locate the most severe shaking, where the greatest damage was likeliest. After the 1994 Northridge earthquake, identifying the damage areas and mobilizing bridge inspection teams took several hours.

Without sufficient data, Caltrans had to locate the earthquake's epicenter, find the closest fault, and develop a list of bridges within a specified buffer zone around the fault or the epicenter. Television newscasts often provided the best indicator of damage areas.

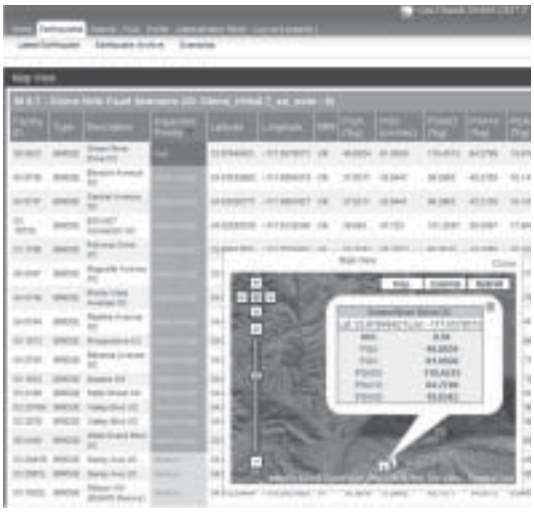
With this information, inspection teams were dispersed widely within the region to perform the initial reconnaissance. This task took up precious time. Moreover, the shaking levels can vary dramatically within a buffer zone. An earthquake rarely ruptures along the entire length of a fault. Furthermore, ground shaking at the same distance from a rupture zone can vary by nearly tenfold, because of various seismological and geotechnical effects. A buffer zone large enough to account for all areas that could have been shaken strongly will include wide swaths of undamaged zones, which can lead to an inefficient use of limited resources.

Solution

In 2005, Caltrans initiated a research contract with the United States Geological Survey (USGS) to develop and implement a Caltrans-specific version of ShakeCast, a postevent software analysis tool. The goal was to change the way that Caltrans responds to a major earthquake. ShakeCast is a web-based application that automatically retrieves measured earthquake shaking data and analyzes the data in relation to individual bridge performance characteristics. Within minutes of an event, the program generates e-mails to set priorities for inspection and assembles other web-based products to assist emergency responders.

ShakeCast was built on ShakeMap, a USGS product that receives measured ground motion data from a network of more than 1,900 sensors throughout California—approximately two-thirds of all sensors nationwide—and combines the information with geological data to create maps that show ground-shaking intensity. The maps provide a level of detail that far surpasses the general information about the earthquake's epicenter and magnitude, which the news media commonly report. ShakeMap provides the input parameters for ShakeCast, which in turn uses the Caltrans bridge and highway inventory data to develop automated analyses and to produce prioritized lists for bridge inspection.

Deployed at Caltrans in June 2008, ShakeCast features Internet-based account management, system administration, and Google Maps visualization tools (see sample screen image, below). In addition, it auto-



ShakeCast website and visualization tools. (MMI = Modified Mercalli Index; PGA = peak ground acceleration; PGV = peak ground velocity; PSA = peak spectral acceleration for 0.3 s, 1 s, and 3 s.)

matically generates products for direct use in Google Earth®, ArcGIS®, and Excel®.

Caltrans operates ShakeCast on two redundant servers at the Transportation Laboratory in Sacramento, supporting a group of responders who perform postearthquake bridge inspections. The servers operate 24 hours a day, 7 days a week, and rely on a robust system of Caltrans e-mail servers to distribute the notifications.

For events greater than magnitude 4.0, ShakeCast automatically determines the shaking value at the locations of more than 12,700 bridges and facilities, compares the values with the threshold preestablished for each facility, and distributes e-mails to designated responders within 15 minutes of the event. The e-mails contain general information about the event and a table of bridges sorted by inspection priority.

Each bridge in the system's database has a unique fragility, determined with bridge damage models originally published by Basöz and Mander (*1*) and implemented in the Hazards U.S. (HAZUS) software of the Federal Emergency Management Agency. The fragility models employ 1-second peak-spectral accelerations and take into account bridge geometry, such as span lengths, number of spans, column heights, and skew; the years of design, construction, and retrofit; and the component material types.

Although the fragility methodology generates probabilities that a structure will be at a defined damage level, the results are presented in the context of inspection prioritization, to avoid any perception that the analysis represents actual damage. Because of the uncertainties in the range of ground motions and the assumptions made in bridge fragility computations, the tool is considered effective in prioritizing resources if the bridges with actual damage in an earthquake were flagged in the top 10 percent of the ShakeCast analysis. Inspection priorities are coded red, orange, yellow, and green, corresponding to high, medium-high, medium, and low priority for full engineering assessment.

Application

The July 2008 earthquake near Chino Hills was magnitude 5.4; only one bridge sustained significant damage. The damage included concrete spalling and transverse displacement of a deck span at the center pier (see photo, this page).

The initial Caltrans ShakeCast notification identified the bridge as the 30th highest inspection priority of the more than 300 bridges assessed. A follow-up notification message, which took into account more comprehensive ground motion measurements, listed the bridge as the third highest inspection priority after assessing more than 400 bridges. Although not considered a major event, the Chino Hills earthquake provided an opportunity to exercise the capabilities of ShakeCast during the test deployment phase and to build confidence in the system.

The Golden Guardian earthquake preparedness exercise[1] in November 2008 deployed ShakeCast to generate assignments for Caltrans bridge inspections. The exercise scenario hypothesized a magnitude 7.8 earthquake on Southern California's San Andreas Fault to test the coordination efforts of regional responders. The Golden Guardian exercise gave Caltrans responders valuable insight into the potential impacts a severe event would have on the highway infrastructure because of bridge damage.

[1] www.shakeout.org/.

Bridge damage from magnitude 5.4 Chino Hills earthquake.

Benefits

The test deployment phase of the ShakeCast software already has realized benefits. The ShakeCast system has proved a valuable tool for Caltrans in postearthquake response during real events and in scenario planning exercises.

ShakeCast facilitates the complicated assessment of potential damage to widely distributed facilities. The system compares the complex distribution of the shaking with the bridge inventory's damageability—which can be highly variable—and provides a simple, hierarchical list with maps of the structures and facilities most likely affected. By focusing inspection efforts on the most critically shaken areas, ShakeCast has drastically reduced Caltrans' response time to assess potentially damaged structures after an earthquake.

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Reference

1. Basöz, N., and J. B. Mander. Enhancement of the Highway Transportation Lifeline Module in HAZUS. Final prepublication draft prepared for the National Institute of Building Sciences, Washington, D.C., March 31, 1999.

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Suggestions for "Research Pays Off" topics are welcome. Please contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).