DRISI

Caltrans Division of Research,
Innovation and System Information

Research Results

Caltrans Bridge Column Demonstrates Resilience in Full-Scale Seismic Test

Ductile column design allows for controlled damage while maintaining load-carrying capacity

Seismic

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Project Title:
Full-Scale Seismic Performance Testing of U.S. Highway Bridge Column

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WHAT IS THE NEED?

Ensuring the seismic resilience of a bridge during and after a major earthquake is of paramount importance to Caltrans. Bridge columns carry the weight of the bridge itself plus the traffic flowing over it, and therefore must be designed to withstand extreme earthquake shaking loads. The Caltrans ductile column designâ€"based on design principles introduced in the 1970sâ€"allows for controlled damage of bridge columns without sacrificing load-carrying capacity. Decades of research experiments have tested and proven the integrity of the ductile design principles, but these experiments were conducted on small-scale specimens or under static loading conditions. Only recently has sufficiently powerful testing equipment become available to test these fundamental seismic-design principles at full scale under dynamic conditions.

WHAT WAS OUR GOAL?

The project's objective was to validate Caltrans' modern seismic design codes for bridge columns and provide benchmark, full-scale test results for evaluating and calibrating past and future experiments conducted at reduced scale or under static loading conditions.

WHAT DID WE DO?

Caltrans, in partnership with researchers at the Georgia ITesting occurred at the UC San Diego Network for Earthquake Engineering Simulation Large High Performance Outdoor Shake Table facility, the largest shake table in the country. The full-scale column test specimen were 24-feet high with a 4-foot diameter, weighing 24 tons. A concrete mass of more than 260 tons was added to simulate the contributing weight of a loaded bridge

superstructure. The column was attached to the shake table through an elongated foundation detailed to have representative performance in the direction of motion. For safety, a standalone steel catcher frame was built around the specimen to prevent catastrophic collapse.

The testing protocol consisted of two series of earthquakes: an initial series of six earthquakes intended to drive the column through a controlled series of damage states beyond Caltrans design standard, and an extended set of repeated extreme motions intended to force the column through even higher damage states. The selection and scaling of these earthquake motions were closely reviewed by Caltrans ground-motion experts to ensure that shaking levels would exercise the full range of design-level loads anticipated within California.

This research is a key component of a collaborative long-term program conducted by Caltrans, the Federal Highway Administration (FHWA), Pacific Earthquake Engineering Research Center (PEER), the National Science Foundation (NSF), and international partners in Japan. Project planning through the Transportation Pooled Fund (TPF) program began in 2008 and was finalized in 2010.

WHAT WAS THE OUTCOME?

The first US-design-based column ever tested at full scale under dynamic loading conditions, this test demonstrated excellent performance that fully validates Caltrans seismic design codes for bridge columns. The results for design-level loading show that column damage occurred in the fuse location near the column base, as per design, and was largely limited to spalling of cover concrete with minor signs of initial buckling of reinforcing bars. This performance was better than anticipated or required.

A series of six additional earthquakes at substantially higher-than-design loading was required to induce ultimate collapse. Here, collapse was defined as the test specimen making contact with the safety frame during dynamic loading. Column performance under these multiple cycles of extreme loading was also better than anticipated or required. Even with the complete rupture of several longitudinal reinforcing bars, the column was capable of supporting the full 260-ton load under static conditions. This test will serve as a benchmark for interpretation of smaller-scale tests.

WHAT IS THE BENEFIT?

These results indicate that Caltrans seismic design standards for a modern ductile column meet and exceed design requirements and should be retained. These findings validate the seismic design principles already embodied in Caltrans Seismic Design Criteria (SDC) and Bridge Design Specifications (BDS).

LEARN MORE

For information about the Outdoor Shake Table:
http://nees.ucsd.edu/facilities

To view a test cycle:
www.youtube.com/watch?v=uF8Fy9KAlis&feature=player_embedded

IMAGES

Figure 1: Close-up view of ductile fuse at column base after completion of all testing