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CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

TRANSFORMING IDEAS INTO SOLUTIONS

Research Notes

Geotechnical/ Structures

MAY 2026

Project Title: Seismically Isolated Bridges under Beyond Design Shaking

Task Number: 4271

Start Date: April 1, 2024

Completion Date: March 31, 2027

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Caltrans

DRISI provides solutions and knowledge that improves California's transportation system.

Seismically Isolated Bridges under Beyond Design Shaking

Conduct experimental and numerical studies to evaluate the behavior of seismically isolated bridge systems under beyond design shaking

WHAT IS THE NEED?

Seismic isolation is considered one of the most effective methods to protect a structure from earthquakes. To this end, the California Department of Transportation (Caltrans) is seeking to increase applications of seismic isolation in bridges towards increasing serviceability of the transportation network following a major seismic event. As described in the Caltrans Memo to Designers 20-22, seismically isolated bridges are designed to remain in full or partial service after a design seismic hazard level earthquake. Damage is accepted under design level shaking for sacrificial components (expansion joints, shear keys, abutment back walls,) allowing for continued or rapid return to service. Isolation bearings are considered the primary Earthquake Resisting Elements (ERS), with a Secondary Earthquake Resisting System (SERS) in the form of developing plastic hinges in the columns under stronger shaking. For beyond design seismic events (an earthquake that exceeds the maximum ground motion explicitly accounted for in a structure's formal design criteria), the behavior of the bridge system with plastic hinging in columns is not well understood with limited studies in the literature. The distribution of deformations between the columns and bearings is critical to predict performance, with column hinging potentially reducing the seismic isolation effectiveness, increasing deformation demand on the substructure.

WHAT ARE WE DOING?

This research will conduct a series of experimental and numerical studies to evaluate the system behavior of seismically isolated bridge systems under beyond design shaking. In particular, the combined behavior of isolation bearings and supporting bents will be tested through failure to better understand the deformation distribution and progression of damage considering system capacity as specified in design codes. The trade-off between critical design parameters such as the response modification factor, the substructure flexibility, and onset of nonlinear behavior will be examined to evaluate the expected seismic performance. Two shake table experiments are planned on quarter scale seismically isolated bridge bents. Each two-column bent is constructed of reinforced concrete and the seismic isolation system consists of four lead rubber bearings placed on top of the bent cap. Experiments will provide data on the distribution of demands within the isolation system and columns, especially as limit states are reached and the bent columns form plastic hinges.

WHAT IS OUR GOAL?

This research aims to better understand how seismically isolated bridges behave under beyond design shaking. By studying how these bridges perform under beyond design shaking, we can confirm whether current design standards provide enough safety and identify where improvements may be needed.

The work will use both lab tests and validated numerical models to examine how bridges respond to strong shaking, focusing on whether the bearings and supporting structures can meet required strength and deformation limits. A major goal is to compare actual performance with what current codes expect.

Primary design parameters (such as isolation design displacement) and design of columns including ductility requirements will be examined. In addition, whether supplemental damping could further reduce demands on the structure and isolation system will be evaluated.

WHAT IS THE BENEFIT?

A key benefit of this research is to validate the underlying analysis assumptions in current design specifications for seismically isolated bridges. The experimental and numerical studies will verify the performance of seismically isolated bridges under beyond design shaking, enabling the verification of numerical models that can be used for performance-based design and risk assessment of bridges. The research outcomes are aligned with Caltrans current plans to increase the application of seismic isolation to ordinary bridges leading to a more robust transportation network.

WHAT IS THE PROGRESS TO DATE?

The research team has focused on the construction of the second specimen for the upcoming shake table tests. The construction of the reinforced concrete two column bent was completed and has been installed on the shake table. The seismic isolation system was modified to reduce the stiffness and composed of two of the same bearings as in Specimen 1 and two new elastomeric bearings (without lead core) currently on order from Dynamic Isolation System Inc. (DIS). The new bearings will first be tested by DIS then delivered to University of Nevada Reno in April 2026 to complete the test setup. In parallel, numerical work has continued to improve the numerical modeling of the bearings and concrete bent using experimental data from Specimen 1. To better capture the initial stiffness of specimen, strain penetration at the column to footing interface has been included. In addition, the prototype bridge model is being modified to include triple pendulum bearings to investigate the post-yield behavior of the bridge system considering engagement of the bearing stiffening regime. The results from shake table testing of Specimen 1 were presented at the CA Bridge Engineer Seminar on February 25, 2026, and at the American Association of State Highway and Transportation Officials Committee on Bridges and Structures Technical Committee Meeting on Seismic Design on January 21, 2026. In the second quarter of 2026, the test setup for Specimen 2 and testing was completed (May 13 (low level testing) and May 15 (beyond design loading)).