MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 22-474 (project 588) | September 2022

Hybrid Bridge Bents Using Post-tensioned Precast Columns for Accelerated Bridge Construction in High Seismic Regions

the ISSUE

Seismic resilience of bridges improves safety and livability of communities. There is a need to improve seismic resilience of bridges for strong earthquakes thus preserving the existing transportation system. New construction techniques, including those suited for accelerated bridge construction, are needed.

the RESEARCH

The project investigates a bridge bent with self-centering precast concrete columns for accelerated bridge construction (ABC) in high seismic regions. The proposed hybrid system consists of post-tensioned precast concrete columns in a two-column bridge bent with one or two buckling restrained braces (BRBs) as external energy dissipation devices. The proposed activity involves testing and analysis of a bridge bent under cyclic loads built with the proposed system. It is expected that the precast columns will remain repairable after strong earthquakes. The BRB devices could be replaced after the earthquake, whereas the gravity load bearing frame should remain undamaged.

Researchers developed a new hybrid bridge system for ABC in seismic regions. In this system, precast post-tensioned columns are combined with a BRB. This is the first time columns reinforced with unbonded post-tensioning (PT) bars are combined with a BRB in a hybrid bridge system.

A reduced scale bridge bent with columns reinforced with unbonded PT bars employed as re-centering elements and a BRB used as an external energy dissipator was tested under cyclic loads. A BRB was connected from the footing at one end to the cap-beam at the other end. A quasi-static cyclic load along with a vertical axial load were applied to the cap beam to determine the seismic capacity and rocking behavior of the hybrid bridge bent. The hysteresis curves were stable and symmetric.

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A University Transportation Center sponsored by the U.S. Department of Transportation serving the Mountain-Plains Region. Consortium members:

Colorado State University
North Dakota State University
South Dakota State University
University of Colorado Denver
University of Denver
University of Utah
Utah State University
University of Wyoming

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Project Title

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the RESEARCH (cont.)

The specimen showed superior lateral displacement capacity with rocking at the joints. The BRB yielded at 1.5% drift ratio and fractured at 5.0% drift ratio. The combination of axial load and post-tensioning force was able to re-center the system; the residual drift ratio was 2.3% when the BRB fractured. The PT bars yielded only after complete fracture of the BRB at 6.0% drift ratio. Not even hairline cracks were observed in the precast column throughout the test. A numerical model was developed in a software framework designed to simulate the performance of structural and geotechnical systems subjected to earthquakes and compared with the experimental results; the numerical model was able to capture the initial stiffness, lateral strength, hysteretic energy dissipation, PT bar force levels, and BRB response with a very good match.

the FINDINGS

Experimental results obtained from quasi-static cyclic tests of the post-tensioned-only specimen and hybrid specimen with a BRB proved the viability of the concept. The experimental results were also compared to numerical models developed in this research. Satisfactory agreement of the numerical models with the experimental results was observed in terms of structural response, hysteretic energy, and post-tensioning forces. The numerical models were extended to a three-column bridge bent for the post-tensioned-only and hybrid configurations. Comparison of the post-tensioned-only and hybrid bridge bents using far-field and near-field ground motions shows that the hybrid bridge bent displays superior performance compared with the post-tensioned-only bridge bent. Specifically, for the extensive damage state, the hybrid bent can tolerate a much higher earthquake demand than the post-tensioned-only bent.

the IMPACT

The hybrid bridge bent with a BRB displays superior seismic performance under simulated earthquake excitations. Moreover, the replaceable feature of the BRBs makes the hybrid bridge bent seismically resilient; the bridge can recover immediately after an earthquake and remain operational. It is recommended that hybrid bridge bents with BRBs can be used in seismic zones due to their reduced residual displacement and higher hysteretic energy dissipation in strong earthquakes.

For more information on this project, download the main report at https://www.ugpti.org/resources/reports/details.php?id=1097

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.