DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Precast Bridge Columns with Energy Dissipating Joints

New designs and materials have better seismic performance and withstand less damage

Seismic

JUNE 2013

Project Title:
Precast Bridge Columns with Energy Dissipating Joints

Task Number: 1999

Start Date: N/A

Completion Date: December 29, 2011

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WHAT IS THE NEED?

Prefabricated bridge systems accelerate bridge construction, minimize traffic delays, and reduce safety risks at the construction site. However, existing precast, segmental columns have limited use in high seismic areas because they provide minimal energy dissipation and sustain significant damage from the discontinuity of longitudinal reinforcement and the rocking action of the end segment. To facilitate accelerated bridge construction, designing precast columns with innovative materials needs to be explored. This study researched whether using fiber-reinforced polymers (FRP), engineered cementitious composites (ECC), and concrete-filled glass fiber-reinforced polymer (GFRP) tubes in precast columns can dissipate energy during an earthquake and minimize potential damage.

WHAT WAS OUR GOAL?

The goal was to develop precast column details that are able to dissipate energy under seismic loads to minimize damage.

WHAT DID WE DO?

Caltrans, in partnership with the University of Nevada, Reno, designed four precast segmental concrete segmental cantilever bridge columns to test different designs and materials. For comparison, one column (SC-2) was constructed with conventional reinforced concrete segments to use as the benchmark. One model had a built-in elastomeric rubber pad in the plastic hinge (SBR-1). The other two columns incorporated ECC (SE-2) and FRP (SF-2) wrapping at the lower two segments. The base segment of each model was connected to the footing with reinforcing bars to provide energy dissipation under seismic loading.

The researchers tested the columns on a shake table by subjecting them to an increasing amplitude of an earthquake until failure. In addition, they tested a precast bent with different low-damage plastic hinges.

WHAT WAS THE OUTCOME?

The researchers observed minimal damage to the plastic hinges and minimum residual displacement in all the innovative column models, which all performed better than the benchmark (SC-2). SF-2 showed the best performance with respect to damage and energy dissipation.

- SBR-1-The elastomeric bearing pad provided increased seismic performance, including larger energy dissipation, larger lateral load and drift capacity, and lower overall damage. SBR-1 reached a 12% larger lateral load than the benchmark.
- SF-2-The advantages of wrapping the first two segments of a column with FRP include a sustainable, large lateral load capacity, increased energy dissipation, and minimum damage at the segmentsâ€™ interface. The lateral load capacity was 30% larger than the benchmark at a drift ratio of 5.3%, and the dissipated energy was 46% more. Using FRP can reduce the concrete crushing and increase the energy dissipation due to increased yielding of the bars.
- SE-2-Using ECC at the plastic hinge results in minimal damage, larger energy dissipation, and lateral load capacity with no strength deterioration for a drift ratio up to 10%. The earthquake energy was dissipated by the bars yielding at the base segment. The amount of dissipated energy was 18% larger than the benchmark.

Using high-damping rubber at the plastic hinge area can minimize damage and increase ductility and energy dissipation. ECC displays substantially higher tensile ductility, tensile strain hardening behavior, and energy dissipation than conventional concrete. FRP wrapping confines the concrete and increases its ductility. GFRP tube is an excellent alternative for accelerated bridge construction because of its light weight, and it eliminates the need for column form work.

WHAT IS THE BENEFIT?

The segmental and precast columns studied have the potential to be used in high seismic zones. They showed relatively large energy dissipation, small damage in the plastic hinge zone, and minimal residual displacement. Incorporating these innovative materials at the base segment provides an alternative for precast columns and can facilitate bridge construction in high seismic zones, leading to less traffic disruption and increased safety for workers.

IMAGES

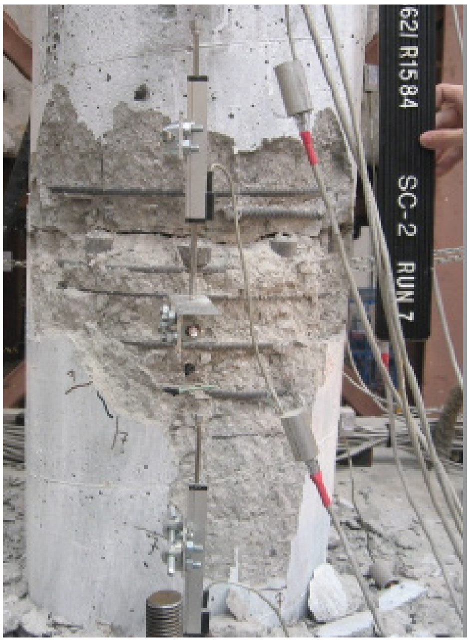

Figure 1: SC-2 (conventional reinforced concreteâ€"the benchmark)

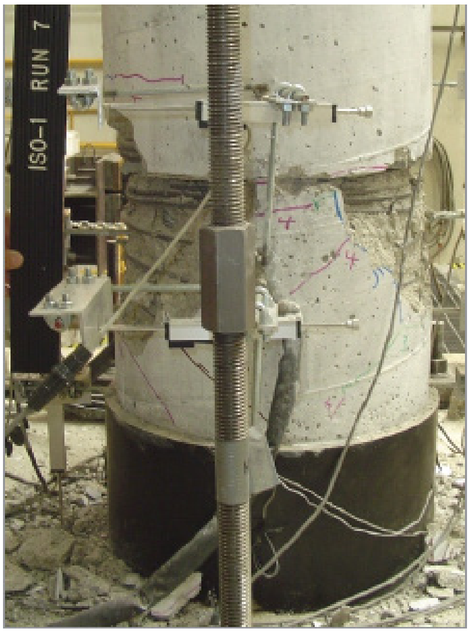

Figure 2: SBR-1 (built-in elastomeric rubber pad in the plastic hinge)

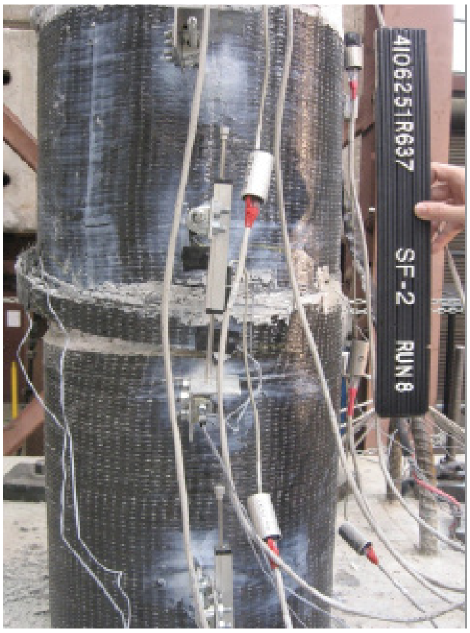

Figure 3: SF-2 (fiber-reinforced polymer wrapping)

Figure 4: SE-2 (engineered cementitious composite wrapping)