Large-Bar Connection for Precast Bridge Bents in Seismic Regions

Jason B. K. PANG
Research Assistant
Civil and Environmental Engineering
University of Washington
Seattle, WA, USA
jasonp54@aol.com

Jason earned a B.S. in civil engineering from the University of Hawaii at Manoa. He is currently a graduate student and research assistant at the UW.

John F. STANTON
Professor
Civil and Environmental Engineering
University of Washington
Seattle, WA, USA
stanton@u.washington.edu

John earned degrees from Cambridge University, Cornell and UC Berkeley. He was a design engineer for six years and joined UW in 1978.

Marc O. EBERHARD
Professor
Civil and Environmental Engineering
University of Washington
Seattle, WA, USA
eberhard@u.washington.edu

Marc earned a B.S.C.E at UC Berkeley. After working as a bridge engineer, he earned graduate degrees at University of Illinois and joined UW in 1989.

Summary

The use of precast concrete components in bents can accelerate bridge construction, but, their use in seismic systems is challenging. Such systems must have connections that are both easy to assemble on site, and have sufficient strength and ductility during earthquakes. A precast bridge bent connection, which uses a small number of large bars anchored in ducts, meets these requirements. Cyclic lateral load tests conducted on subassemblies of the system demonstrated that it has strength and ductility similar to those of a comparable cast-in-place connection. Intentional debonding of a short length of the bars had little effect on performance.

Keywords: rapid-construction; precast connections; bridge bent; substructure; grouted ducts; anchorage; debonding

1. Introduction

Researchers at the University of Washington, in cooperation with engineers from the Washington State Department of Transportation, contractors, and precast fabricators have developed a precast bridge bent system that is rapidly constructible.

The system features a precast column and precast bent-cap, connected at the beam-column interface onsite. Details for the full-scale connection are shown in Figure 1. The prototype connection consists of 6 D57 (#18 in U.S. practice) vertical column bars grouted into 216-mm diameter corrugated metal ducts embedded within the bent-cap. The few large bars fitted into large-diameter ducts provide generous construction tolerances and good constructability.

This paper presents the results of four, 40-percent scaled subassembly tests conducted to evaluate the seismic performance of the proposed system.

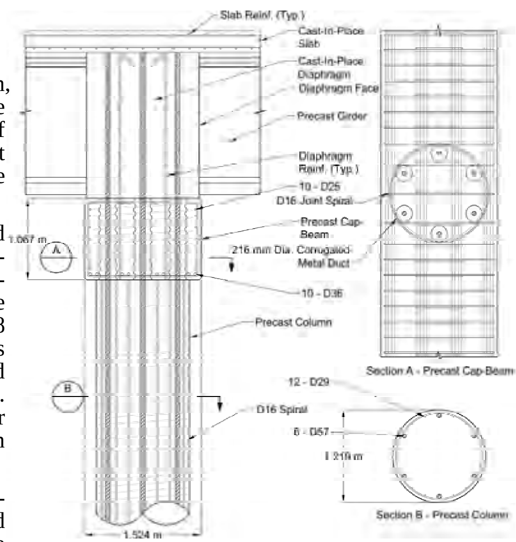

Figure 1: Details of the full scale connection

2. Subassembly Tests

All specimens included a 0.445-m deep cap-beam, a 0.470-m deep portion of the diaphragm, and a 1.524-m tall segment of the 0.508-m diameter column. They were tested in the inverted position

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under constant axial load and a cyclic lateral-displacement history.

Three variations of the proposed connection were tested, all reinforced with 6 D25 bars, anchored in 101.6-mm grouted ducts embedded in the cap-beam and within concrete in the diaphragm. In LB8-FB those bars were fully bonded in grouted ducts. In LB8-D1 and LB8-D2, those bars were debonded 8-bar diameters near the beam-column interface to reduce the strain concentration that might otherwise occur there because the bond resistance provided by the grouted duct is high. The fourth specimen, DB8-RE, was a typical cast-in-place column reinforced with 16 distributed D16 bars anchored in concrete in the cap-beam and diaphragm. It served as a reference with which to evaluate the proposed precast system.

3. Experimental Results

All four specimens demonstrated nearly identical equivalent moment-drift responses and damage. They maintained 80 percent of their peak lateral resistance out to drift ratios of roughly 5.5 percent and ultimately failed as a result of bar fracture at roughly 6.5 percent. These drift levels greatly exceed the drift demands expected in a bridge bent for even a large earthquake.

The majority of deformations in the precast specimens resulted from a large, localized crack opening at the interface. Rotations measured over the bottom 38 mm of the column accounted for more than 90 percent of the total column displacement. In contrast, the curvature in Specimen DB5-RE was more evenly distributed over the bottom 1.0 m of the column, as is common in cast-in-place systems.

All specimens had nearly identical energy dissipation capacities at similar drift ratios. The strength and stiffness drastically reduced at a drift ratio of approximately 6.5 percent, due to buckling and bar fracture.

The types and amount of physical damage were nearly identical for all specimens. Damage consisted of spalling of the concrete cover, bar buckling, spiral fracture, and ultimately bar fracture. These damage milestones occurred in each specimen at nearly the same drift levels of roughly 2, 5, 5.5, and 6.5 percent, except that bar fracture in DB5-RE was delayed to 8.8 percent. Bar fracture occurred on the tension half cycle following bar buckling. LB8-FB experienced considerable spalling of the beam surface and radial cracking propagating from around each duct, beginning at 1.6 percent drift and increased through the test.

In LB8-D1 and LB8-D2, the bars were intentionally debonded in the cap-beam to reduce the maximum strain at the interface and distribute bond stresses deeper in the beam instead of at the surface due to the superior bond in grouted ducts. Debonding had little affected the hysteretic performance of the system. Also, there was no measurable difference in performance between the two specimens with the two debonding methods. However, the stiffness at small drifts was slightly greater in LB8-FB than in LB8-D1 and LB8-D2. As the bars in LB8-FB and DB5-RE debonded themselves in the column, the behavior approached that of the intentionally debonded specimens. Intentional debonding did eliminate spalling damage to the surface of the cap beam by anchoring the bar deeper in the beam.

4. Conclusions

The primary conclusions of the study are presented below:

1) The proposed bridge bent system performed well. The test specimens maintained energy dissipation maintained most of it resistance to a drift of more than 6 percent, ultimately failing as a result of bar buckling, followed by bar fracture.
2) The majority of deformation of the precast system was concentrated at one large crack at the beam-column interface. This behavior differed from the typical cast-in-place reinforced concrete connection, in which deformations were distributed more evenly.
3) Debonding of the longitudinal column bars in the cap beam had little effect on the overall hysteretic performance of the system. It reduced the stiffness slightly under low loads.
4) Debonding of the bars did not delay bar fracture. Fracture occurred as a result of the low-cycle fatigue cause by buckling.