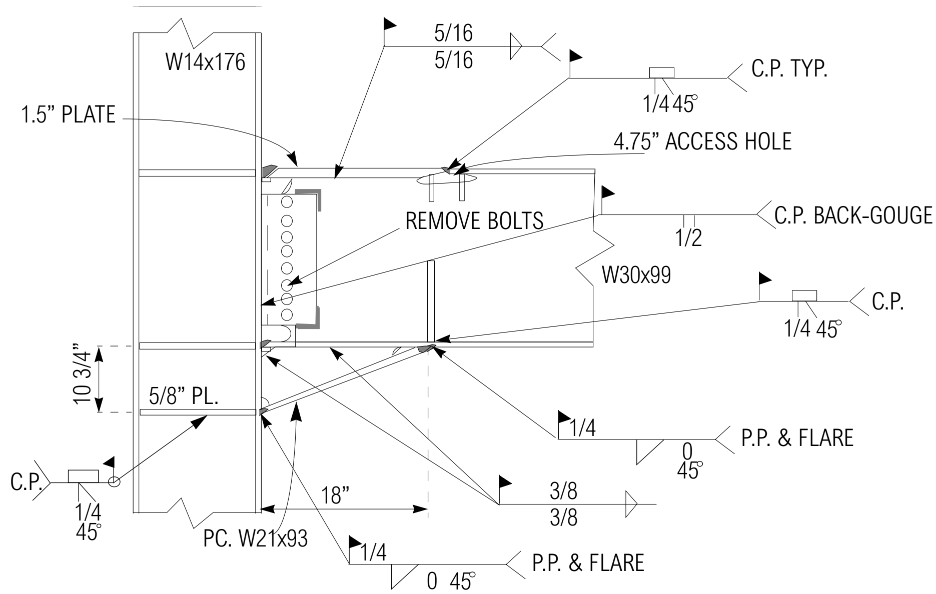
SAC Steel Project

Test Summary No. 19

the FEMA Program to Reduce the Earthquake Hazards of Steel Moment Frame Structures

Specimen ID:	UCSD-3R
Keywords:	Repaired, replacement top plate, bottom haunch, beam web to column weld, local buckling, increased energy dissipation, medium rotation capacity
Test Location:	University of California, San Diego
Test Date:	April 28, 1995
Principal Investigator:	Chia-Ming Uang; with Duane Bondad
Related Summaries:	6
Reference:	"Experimental Investigations of Beam-Column Subassemblages", *Report No. SAC 96-01*, March 1996.
Funding Source:	FEMA / SAC Joint Venture, Phase I

CONNECTION DETAIL



MATERIAL PROPERTIES AND SPECIMEN DETAILS

Member	Size	Grade	Yield Stress (ksi)		Ultimate Strength (ksi)	
			mill certs.	coupon tests *	mill certs.	coupon tests *
Beam	W30X99	A36	49.3	46.5 flange 57.1 web	71.8	67.7 flange 72.5 web
Column	W14X176	A572 Gr. 50	55.0	52.5 flange 51.2 web	74.5	68.2 flange 67.2 web
Haunch	W21X93	A36	N.A.	39.0 flange 39.8 web	N.A.	64.0 flange 69.2 web
Vertical Stiffener	1/2” plate	A36	N.A.	45.2	N.A.	66.9
Replacement Plate	1 1/2” plate	A36	N.A.	42.2	N.A.	71.4

Welding Procedure Specification	All welds FCAW-SS in conformance with AWSD1.1-94, performed with 0.120” diameter AWS E70T-4 electrodes. Preheat and interpass temperature per Table 4.3. Fillet weld of shear tab to beam web performed with 0.072” diameter AWS E71T-8 electrode. All repairs performed using 0.072 in. diameter AWS E71-T8 electrode.
Shear tab	3/8 x 5” plate, remove bolts, groove weld beam web to column flange
Panel zone	No doubler plates
Continuity plates	3/8” plates with c.p. weld ; add a 5/8” plate at the haunch level with 1/4” c.p. weld
Boundary conditions	Single-sided test, no floor slab, axial load in lower half of column equal to shear in beam, specimen tested in upright position
Other detailing	Repair beam bottom flange groove weld, add vertical stiffeners at replacement plate access hole

N.A. = not available

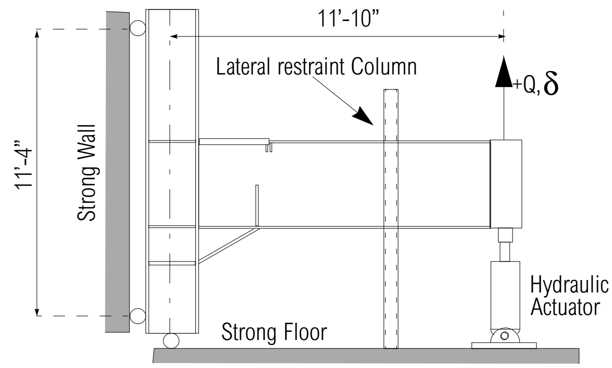
* Coupon locations per ASTM

BACKGROUND

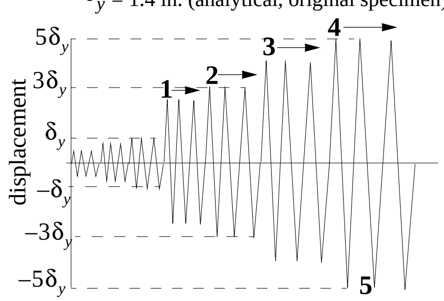
This was a test of repairs on specimen UCSD-PN3 (Test Summary No. 6) that was originally tested on March 2, 1995. The original specimen experienced sudden failure in the beam top flange groove weld during the first negative displacement excursion to $3\delta_y$ (where δ_y = 1.40 in., obtained from analytical studies of the original specimen). The failure of the specimen was preceded by shear yielding in the panel zone. Additionally, during the cycles to $2\delta_y$, the specimen experienced fractures at the top and bottom ends of the shear tab and fractures at the top and bottom web access holes. The cyclic tests were performed quasi-statically.

The specimen repair procedure consisted of torch cutting and removing a 20-in. long portion of the beam top flange, torching a 4.75 in. wide inclined access hole, replacing the cut beam top flange with a 1.5” thick plate, welding the replacement plate to the column and beam flanges, fillet welding the plate to the beam web, removing the backup bars and running a final weld pass, welding 4” vertical stiffeners at the access hole, removing the shear tab bolts, groove welding the beam web to the column flange, welding the flange of the haunch to the column and beam flanges, fillet welding the haunch web to the column and beam flanges, installing additional horizontal continuity plates, and installing vertical stiffener plates. The objective of this repair scheme was to force plastic hinging in the beam to occur away from the column face. The standard SAC/ATC-24 loading history was used in the quasi-static testing of the repaired specimen, and a yield displacement (δ_y) of 1.40 in. was assumed to provide consistency with the previous test.

TEST SET-UP



DISPLACEMENT HISTORY AND KEY EXPERIMENTAL OBSERVATIONS

Applied Displacement History	Key Observations of the Test	
	Point	**Description**
δ_y = 1.4 in. (analytical, original specimen) 	**1**	Minor local buckling and yielding of beam flanges
	2	Significant local buckling of beam flanges outside haunch and replacement plate; gradual degradation of strength
	3	Further reduction in load carrying capacity due to severe buckling; yielding of stiffeners
	4	Presence of second mode of buckling (reverse curvature)
	5	Fracture in beam web just below the top flange fillet line due to severe local buckling

DETAILED TEST RESULTS

Quantity (see Introduction for definitions used in UCSD tests)		Maxima
Force/Displacement Properties	Peak actuator force (kips):	~155
	Beam tip displacement (in.):	7.6
	Experimental yield displacement (in.)	1.48
Rotation Capacity	Maximum plastic rotation (% radian):	5.2/4.5 prior to strength degradation below $0.8M_p$
	Cumulative plastic rotation (% radian):	85.6 (including degraded portion)
Energy Dissipation Properties	Cumulative energy dissipated (k-in.):	10,740 (including degraded portion)

Mode of failure: Fracture in beam web just below the top flange fillet line during the $5\delta_y$ cycle.

DISCUSSION

Very minor local buckling in the beam flanges of specimen UCSD-3R was observed during displacement cycles to $2\delta_y$. Significant flange local buckling outside the haunch and the replacement plate caused a gradual strength degradation during the displacement excursions to $3\delta_y$. Minor lateral torsional buckling was also observed during these cycles. During the displacement excursions to $4\delta_y$, severe local buckling caused further reduction in the load carrying capacity. Yielding of the top end of the stiffeners was apparent. The second buckling mode (reverse curvature) was noted on one side of the web at the top flange during the displacement cycles to $5\delta_y$. High curvature in the beam web resulting from the severe local buckling created a horizontal fracture just below the top of flange fillet line during the second negative excursion to this displacement. The maximum plastic rotation of the connection was approximately 5.2% radian. Most of the inelastic deformations were concentrated in the beam. By connecting the beam bottom flange to the column flange, the tendency for lateral torsional buckling to develop in the beam in this region was minimized. Panel zone shear yielding was primarily concentrated in the upper portion. The short vertical stiffeners at the top flange repair access hole ensured that the plastic zone in the beam top flange developed away from the column face, and prevented premature failure due to web out of plane buckling.