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Executive Summary Report:
FHWA Bay Bridge Pile Connection Plate Welding Investigation
By John W. Fisher PhD, PE

Following is a brief summary of my findings on the partial penetration welds that connect the vertical pile head shear plates to the pile sleeves in the steel foundation boxes which were alleged to be improperly made.

Examination of the Contractors QC and Caltrans QA requirements demonstrated that the job conformed to the AWS specifications and exceeded those used in most states. The welds were machine made with E71T-1 flux core electrodes which was found to produce welds with excellent notch toughness and strength. QC and QA throughout the welding of each connection resulted in a portion of each weld pass being visually examined. The root pass and the cap passes were all magnetic particle inspected.

Although early in 2003, problems developed with the highly restrained joints in the shear plate to pile and pile sleeve connections as a result of hydrogen cracking and brittle fracture when the crack extended into the pile or pile sleeve base metal, those problems were corrected. The welding equipment was replaced, run-out tabs were used at the access holes at the ends of the connection plates to start and stop each pass of the PJP welds, and increased preheat was provided at the bottom end of the connection to offset heat loss. After welding, the run-off tabs were removed and the access hole areas profiled and ground smooth to insure removal of unacceptable discontinuities. The access hole base metal was also ultrasonically tested to insure that no unacceptable discontinuities remained. These procedures have prevented subsequent fractures.

Our site visit to Pier E4W provided a first hand look at connections in a variety of conditions. This ranged from a joint with only the root pass and the welding machine and heating pads in place; several connections with the run-off tabs removed after welding and the access holes shaped by torch, to a connection with the access hole region ground smooth. None of the connections were indicated to have had the QC/QA completed. The physical appearance of all weld passes was normal and characteristic of vertical up welding.

The limit states of the pile, pile sleeves, connection plates and the partial penetration joint welds were evaluated. That demonstrated that the partial joint penetration welds had a shear capacity that exceeded the yield force that the pile and connection plates could deliver to the welds by a substantial margin. Furthermore, weld qualification tests indicated that the weld metal had high values of notch toughness and would be very resistant to fracture from assumed large cracks.

The results of the field inspections and the destructive examination by Mayes Testing Engineers of the full depth weld samples removed from Pier W4E at Pile 2B, Pile 3G and Pile 5D demonstrated that the welds showed excellent workmanship and no evidence of major and unacceptable discontinuities.

It was concluded that:

1.) The weld quality provided in the steel footing boxes for the connection of the steel piles to the pile sleeves was found to be very good. The QC/QA provided by this project equals or exceeds that required by most states.

2.) The partial joint penetration welds (PJP) used to connect the vertical pile head shear plates to the piles and the pile sleeves are very conservative in their design. Their design limit state exceeds the shear yield capacity of the connection plate and the maximum yield capacity of the pile by over 100%.

3.) Weld qualification test data demonstrate that the E71T-1 weld metal provided high levels of fracture toughness. Normal fabrication defects and even a 1/4in. deep crack in the weld metal at the access holes region would not result in crack instability if subjected to yield level loads during an earthquake.

4.) The pile cap design provides a very high level of redundancy with many alternate load paths. There should be no concern with the capacity and performance of the steel pile pier caps and their welded connections. Even if a fracture occurred in one of the shear plate welds, the other weld could still transfer the load to the shear plate.

5.) Traffic loads will produce negligible cyclic stresses in the concrete encased, concrete filled steel pier caps. There is no possibility of fatigue crack extension from cyclic loads in service. The cycle frequency from earthquakes is infrequent and will not enlarge any defect in low cycle fatigue, since millions of cycles are required for cracks to form and propagate.