Economic Seismic Connection Repairs:

Weld Overlays

A new study indicates that earthquake-damaged connections can sometimes be repaired by depositing a higher grade weld overlay

Top and bottom flange overlays after testing

A NEW REPORT ISSUED BY AN INDEPENDENT GROUP OF RESEARCHERS has suggested that weld overlays can be used to return earthquake-damaged connections to their pre-earthquake condition. The DLW Task Group, which includes a number of respected West Coast engineers, has carried out a series of small component tests to investigate the dynamic capability of the weld overlays. Subsequently, the group conducted large-scale beam-to-column connection tests to verify the overall elastic and ductile behavior of the connection.

According to the group's report: "The principle of the overlays is essentially to deposit a higher grade overlay using weld with material(s) very resistant to fracture initiation and propagation, and which can immobilize numerous defects in the weld metal, heat affected zone and base metal. The overlay will perform to its specific load requirements using the most suitable welding process and inspection procedure. The surface layer is required to provide the highest dynamic load resistance based on the fracture mechanics principle that fracture generally initiates at the surface. With the presence of the overlays, defects are distanced from the surface and become immobilized whether detectable or non-detectable."

The study had a number of interesting results:

- The small component specimens, utilizing the shielded

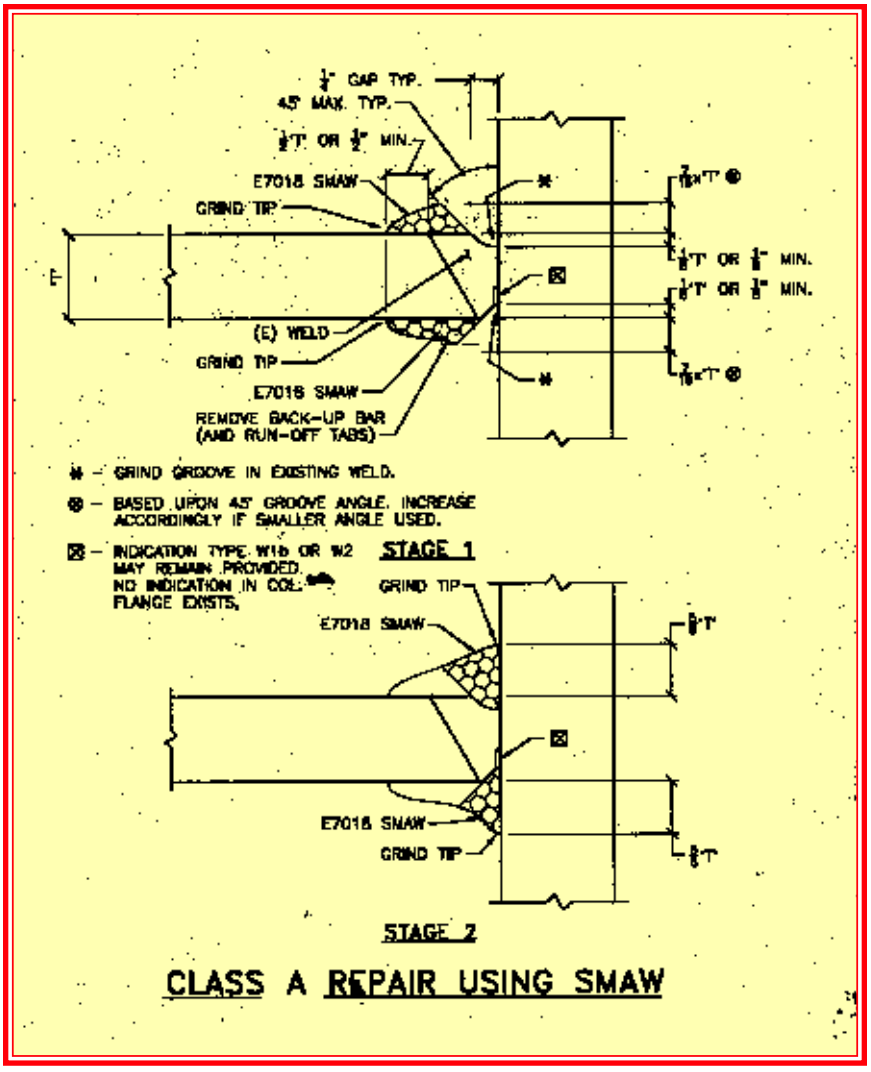
metal arc weld (SMAW) process, with vertical and with cruciform defects, attained large deformations before fracture when subjected to a drop weight test. Although there was a very slight propagation of internal defects, fracture occurred elsewhere, typically away from the internal defects.

- The small component specimens, utilizing SMAW welded overlays and with vertical defects, tested by low cycle fatigue tests, exceeded 600 cycles before fracturing. Again, fracture did not initiate at the internal defects.
- The two large-scale beam column tests showed excellent performance. One specimen, with the significant rotation occurring in the panel zone, failed at the top flange from the web cope area in the parent metal (away from the overlay), to the heat affected zone at the top side of the beam flange, which did not have an overlay. At the bottom flange, where an existing crack occurred, the overlays on both sides of the beam flange were sufficient to accommodate the severe axial and flexural stresses and strains. The second specimen, strengthened with a double plate at the panel zone, displayed substantial local buckling of the flanges and web. Yet the original welds, strengthened with overlays on both sides of the flanges, sustained the severe axial force and bending at the joints with the primary fracture occurring at the top flange well away from the overlays.
- The initial study clearly demonstrates very positive value engineering benefits.

Repair Types

The study classified the various types of repairs as follows:

Class A: If dynamic joint efficiency is under 50% or has not been determined, apply a maximum overlay with SMAW to supplement the joint deficiency to arrive at a joint which will take the full load demand and existing column flange heat affected zone.



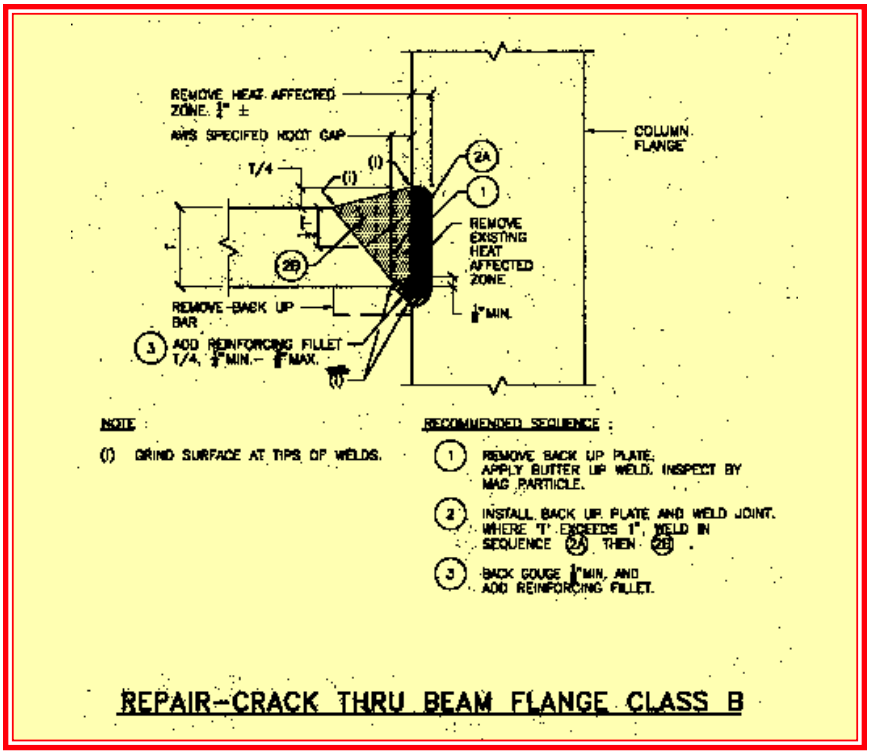
Class B: Gouge out the entire weld and column flange heat affected zone and replace with SMAW and add a fillet weld.

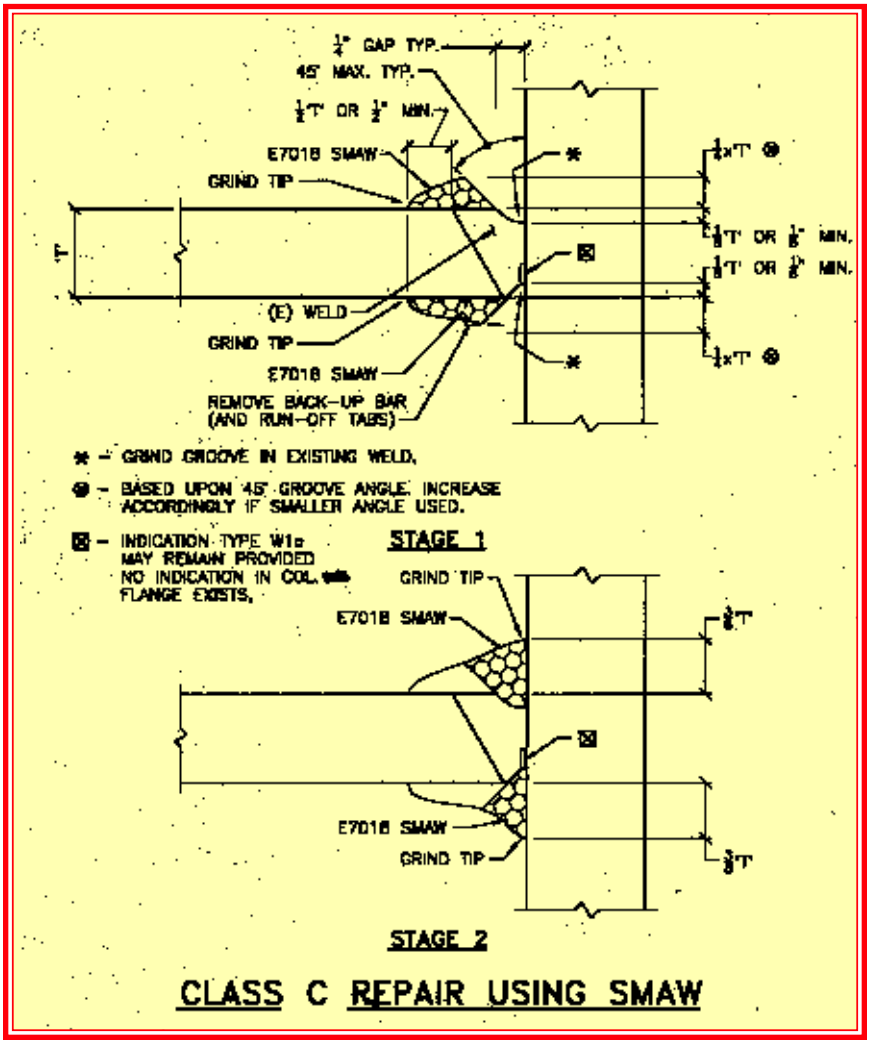
Class C: If the dynamic Joint efficiency is over 50%, apply a minimum overlay with SMAW to supplement the joint deficiency.

Class D: Failure of a major structural element, e.g. column separation, replace the failed element using SMAW for repair.

Class B represents the conventional repair currently being carried out on major cracks in beam flange welds on repair projects in Los Angeles, while Classes A and C represent repairs using weld overlays. Class A is intended to be used for significant indications in the beam flange weld. Class C is for minor indications in the beam flange weld. The sequencing of the welds is such as to minimze the build up of residual stresses. Class D primarily represents column flange and web cracking and is beyond the scope of repair using weld overlays.

A cost study showed that the use of weld overlays cost approximately one-third as much as the conventional repair (Class B) method. In one cost study, a unit cost of 1.0 was assigned to the Class B repair (0.66 for the top flange repair and 0.34 for the bottom) using SMAW. The unit cost was for medium size members. In contrast, the Class A repair had a cost of 0.29 (01.5 for the top flange and 0.14 for the





bottom) and the Class C repair had a cost of 0.23 (0.12 for the top flange and 0.11 for the bottom).

Recommendations

The research team also offers a number of recommendations, based on the study.

Minor indications in the beam flange weld (Type W1A as defined in SAC's Interim Guidelines), if they require repair, may be repaired using Class C. From interpretation of the test data (e.g the large scale test on specimen 1, where failure occurred at the top flange with only a single overlay applied), Class C will perform significantly better than the conventional repair of minor cracks.

Major indications in beam flange weld (Type W1B and W2) may be repaired using Class A welded overlays. The conventional repair, Class B, using notch tough welds, from a previous large-scale test performed well but failure occurred by propagating from the web cope through the beam flange. Based upon the evidence of the tests, Class A repairs appear to provide better performance than the conventional repair Class B. Reinforcing the conventional repair with overlays will significantly improve its overall static behavior and dynamic performance.

Limitations

The task group did advise caution in the use of overlays, however. According to the report: "Although the tests have shown excellent results, the use of overlays should be considered, at this point in time, as a repair method. i.e. restoring the connection to its pre-existing condition or better. More testing, including small component tests on larger thicknesses (greater than 1 inch) and large-scale tests on larger members is recommended before it may be considered a retrofit method. These limitations are anticipated to be revised, following additional testing. Small

component tests on larger thicknesses are intended to be carried out within the next six months." Further, the report noted that preheat was not applied to any of the small scale and large-scale specimens. "However, until further testing is carried out, the recommendations of FEMA 267 and the City of Los Angeles' recommendations for the repair of welded steel frame connections existing buildings should apply," the report noted.

A full copy of the 59-page report, "Dynamic Load Welds for Repair of Existing Steel Moment Frame Buildings Damaged from Earthquakes," is available for $45 (which includes postage and handling) from the DLW Task Group, c/o Sitech Ltd., P.O. Box 3532, Winnetka, CA 91396-3532.

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