SAC
Steel Project

Background Document

Dynamic Tension Tests of Simulated Welded Beam Flange Connections

Report No. SAC/BD-00/07

SAC Joint Venture

A partnership of
Structural Engineers Association of California (SEAOC)
Applied Technology Council (ATC)
California Universities for Research in Earthquake Engineering (CUREe)

By
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Submitted for distribution to
SAC Joint Venture
650-595-1542
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DISCLAIMER

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THE SAC JOINT VENTURE

SAC is a joint venture of the Structural Engineers Association of California (SEAOC), the Applied Technology Council (ATC), and California Universities for Research in Earthquake Engineering (CUREe), formed specifically to address both immediate and long-term needs related to solving performance problems with welded, steel moment-frame connections discovered following the 1994 Northridge earthquake. SEAOC is a professional organization composed of more than 3,000 practicing structural engineers in California. The volunteer efforts of SEAOC's members on various technical committees have been instrumental in the development of the earthquake design provisions contained in the *Uniform Building Code* and the 1997 *National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and other Structures*. ATC is a nonprofit corporation founded to develop structural engineering resources and applications to mitigate the effects of natural and other hazards on the built environment. Since its inception in the early 1970s, ATC has developed the technical basis for the current model national seismic design codes for buildings; the *de facto* national standard for postearthquake safety evaluation of buildings; nationally applicable guidelines and procedures for the identification, evaluation, and rehabilitation of seismically hazardous buildings; and other widely used procedures and data to improve structural engineering practice. CUREe is a nonprofit organization formed to promote and conduct research and educational activities related to earthquake hazard mitigation. CUREe's eight institutional members are the California Institute of Technology, Stanford University, the University of California at Berkeley, the University of California at Davis, the University of California at Irvine, the University of California at Los Angeles, the University of California at San Diego, and the University of Southern California. These laboratory, library, computer and faculty resources are among the most extensive in the United States. The SAC Joint Venture allows these three organizations to combine their extensive and unique resources, augmented by subcontractor universities and organizations from across the nation, into an integrated team of practitioners and researchers, uniquely qualified to solve problems related to the seismic performance of steel moment-frame buildings.

ACKNOWLEDGEMENTS

Funding for Phases I and II of the SAC Steel Program to Reduce the Earthquake Hazards of Steel Moment-Frame Structures was principally provided by the Federal Emergency Management Agency, with ten percent of the Phase I program funded by the State of California, Office of Emergency Services. Substantial additional support, in the form of donated materials, services, and data has been provided by a number of individual consulting engineers, inspectors, researchers, fabricators, materials suppliers and industry groups. Special efforts have been made to maintain a liaison with the engineering profession, researchers, the steel industry, fabricators, code-writing organizations and model code groups, building officials, insurance and risk-management groups, and federal and state agencies active in earthquake hazard mitigation efforts. SAC wishes to acknowledge the support and participation of each of the above groups, organizations and individuals. In particular, we wish to acknowledge the contributions provided by the American Institute of Steel Construction, the Lincoln Electric Company, the National Institute of Standards and Technology, the National Science Foundation, and the Structural Shape Producers Council. SAC also takes this opportunity to acknowledge the efforts of the project participants – the managers, investigators, writers, and editorial and production staff – whose work has contributed to the development of these documents. Finally, SAC extends special acknowledgement to Mr. Michael Mahoney, FEMA Project Officer, and Dr. Robert Hanson, FEMA Technical Advisor, for their continued support and contribution to the success of this effort.

PREFACE

The primary objectives of the FEMA/SAC Phase II Steel Project are to develop guidelines for the seismic evaluation, inspection, repair, design and construction of moment resisting steel frame buildings. A diverse collection of technical investigations is supporting this effort, including the identification of basic material properties in rolled steel sections; development of appropriate welding materials, details, and inspection procedures; specification of anticipated seismic demands imposed on connections as a result of structural response to strong ground motions; and large-scale connection testing to calibrate and verify the design procedures that are ultimately proposed. Tying these activities together is a series of detailed finite element analyses of various connection configurations to quantify the influence of material properties, geometry, and detailing on predicted behavior. In addition, a series of studies have been performed to incorporate the results of the various investigations into a performance based seismic engineering format that can become the basis of the SAC guidelines. Cost and risk studies and investigations into the past performance of this class of structures were also performed to gather valuable information used in the development of the guidelines and other documents.

The primary responsibility of the Connection Performance team in the Phase II Steel Project is to develop straightforward and reliable design and analysis tools for seismic moment resisting connections in steel frame structures. This report documents the results of an experimental investigation on improving the performance local joint details that are used as part of welded moment connections for use in seismic resistant construction. Issues such as notch toughness of weld metal, the use of grooved backing bars, and beam flange weld reinforcement were all studied as part of the investigation. The experimental work included fifteen large scale tension tests. It is understood that this procedure does not duplicate the strain demands on welded joints in actual connections. But, these tests can help to understand the influence of key parameters on joint performance. It was found that the application of a continuous fillet weld with notch tough filler metal to the weld backing of a weld made with low toughness material does not significantly improve the performance of the joint. In addition, the use of grooved backing bars does not significantly improve the performance of welds made with low toughness material. The tests also indicated that ductile performance can occur on notch tough welds where the weld backing is left in place. This project was performed at Lehigh University. This task was identified as part of Task 7.05 of the SAC Phase II program.

Numerous individuals helped to develop the scope and content of the project and to review a preliminary version of this report. These individuals included members of the Technical Advisory Panel (TAP) for Connection Performance; selected members of the Joining and Inspection TAP; and several members of the Project Oversight Committee. The contributions of these individuals are greatly appreciated.

ABSTRACT

Fifteen tension specimens that simulated the tension beam flange of a welded beam-to-column connection were tested. Each of these tests was conducted at a high strain rate. The variables investigated in this study included: (1) notch toughness of weld filler metal; (2) grooved backing bars; and (3) beam flange weld reinforcement. Although it is recognized that loading conditions occurring in a full-scale connection are not duplicated in a tension specimen, the purpose of the tests was to provide an understanding of the key material and welding factors that can lead to poor connection performance and methods of improving performance. Based on the test results it was found that retrofitting weld joints with E70T-4 filler metal through the placement of a continuous notch tough fillet weld reinforcement does not improve performance. In addition, the use of grooved backing bars does not improve the performance of specimens with E70T-4 filler metal. The performance of specimens with E70TG-K2 filler metal was affected by the positioning of the grooved backing bar, where the misalignment of the backing bar can cause entrapment of mill scale or slag, creating a flaw and leading to a potential weld failure. Specimens using E70TG-K2 filler metal and a backing bar of standard geometry performed in a ductile manner. Leaving the backing bar in place without a reinforcement fillet weld was found to produce a ductile response. The results of the study support the current SAC recommendation for weld metal used in critical joints to have a minimum CVN impact toughness in conjunction with good weld detailing such as the removal of weld backing bar and control of weld flaws through inspection.

ACKNOWLEDGMENTS

Funding for this research was provided by grants from the Federal Emergency Management Agency through the SAC Joint Venture and the Department of Community and Economic Development of the Commonwealth of Pennsylvania through the Pennsylvania Infrastructure Technology Alliance (PITA). SAC is a partnership of the Structural Engineers Association of California, the Applied Technology Council, and California Universities for Research in Earthquake Engineering. This research was conducted as Task 7.05 under Phase II of the SAC Joint Venture.

Mr. James O. Malley is the Project Director of Topical Investigations for the SAC Joint Venture. PITA is co-directed by Dr. Pradeep Khosla and Dr. John Fisher.

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