SAC
Steel Project

Background
Document

Preliminary Evaluation of Heat Affected Zone Toughness in Structural Shapes used in the Construction of Seismic Moment Frames

Report No. SAC/BD-00/13

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

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Submitted for distribution to
SAC Joint Venture
650-595-1542
http://www.sacsteel.org

October 17, 2000

DISCLAIMER

This document is one of a series documenting background information related to Phase II of the FEMA-funded SAC Steel Project. It is being disseminated in the public interest to increase awareness of the many factors which contribute to the seismic performance of steel moment frame structures. The information contained herein is not for design use and is not acceptable to specific building projects. This report has not been reviewed for accuracy, and the SAC Joint Venture has not verified any of the results presented. **No warranty is offered with regard to the recommendations contained herein, by the Federal Emergency Management Agency, the SAC Joint Venture, the individual joint venture partners, or the partner's directors, members or employees. These organizations and their employees do not assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any of the information, products or processes included in this publication. The reader is cautioned to review carefully the material presented herein and exercise independent judgment as to its suitability for application to specific engineering projects.** This publication has been prepared by the SAC Joint Venture with funding provided by the Federal Emergency Management Agency, under contract number EMW-95-C-4770.

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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.

This report was carried out as part of the overall efforts of the Welding and Inspection team of the SAC Phase II Steel Project. This team was responsible for assessing the factors that effect the behavior of complete joint penetration welds of the type used in steel beam to column connections, assessing the ability of nondestructive evaluation methods to detect and characterize weld defects, and developing weld acceptance criteria considering the properties of the welds, the applied deformations or stress conditions, and likely local defects and imperfections. A variety of tests, theoretical studies and finite element analyses were conducted as part of this task. The work in this task was closely linked to parallel efforts and full size connections tests carried out by the Connection Performance and Materials and Fracture teams.

This report focuses on a series of technical studies to assess the effect of welding procedures on the properties of the heat-affected zone between weld and base metal in a complete penetration welded joint in a beam to column connection. This work was used to identify any potentially adverse effects of welding procedures on the HAZ that might detrimentally effect the behavior of the welded joint. This work was conducted at the Edison Welding Institute in Columbus, Ohio. This project was identified as Task 5.2.7 in the SAC Phase II work plan.

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

Abstract

The regions found in single pass and multipass weld metal heat affected zones (HAZ) are reviewed. A simple overview of how toughness is measured in the HAZ is presented along with a review of basic factors that influence heat affected zone toughness. Limited evaluation of CVN impact test data measured in ASTM 572 Gr. 50 along with a review of HAZ toughness data from ASTM A913/ASTM 572 Gr. 50 suggests that the HAZ toughness should meet or exceed base metal toughness when reasonable welding heat inputs are maintained. Production of steel to ASTM A913 and A992 specifications is expected to result in steels with improved weldability relative to those produced to A572 Gr. 50 or A36 specifications. Review of steel chemical compositions for structural shapes used in the SAC projects suggest that microalloying elements such as niobium and vanadium were either intentionally or unintentionally added. Current provisions of the ASTM A992 specification allow for production of silicon killed steel with no microalloy addition. Additional consideration should be given to microalloying practice in structural grade steels where the potential for deposition of welds with high heat inputs exists.