SAC
Steel Project

Background
Document

Selected Results from the SAC Phase I Beam-Column Connection Pre-Test Analyses

Report No. SAC/BD-96/01

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
http://www.sacsteel.org

May 1996

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 SAC Joint Venture, under Phase I funding from the Federal Emergency Management Agency, coordinated a series of pre-test analyses in which practitioners and researchers were invited to submit blind analytical predictions of the performance of a welded steel beam-column connection scheduled to undergo testing. The materials and geometry of the test specimen, which was designed in accordance with the *Interim Guidelines* for steel moment frame structures, were provided to the analysts before the test was performed. After testing was completed, a meeting was held in which the analytical predictions were compared with the experimental results.

A total of fourteen studies were submitted encompassing a wide range of analytical solutions, including large-scale, fully nonlinear finite element analyses, simplified nonlinear models using programs such as DRAIN-2DX, linear and nonlinear fracture analysis approaches, Monte Carlo simulations, plastic work methods based on hand calculations, and energy-based evolutionary damage mechanics models. All of the submissions were of very high quality, but the two submissions, reproduced in this report were identified by a panel of judges as particularly worthy of distinction, and each of these investigators received a small stipend to fund their efforts. A third investigation was also recognized for its excellence, but permission was not granted for the report to be published in this volume.

The SAC Joint Venture thanks all of those who participated in the pre-test analyses for their contributions toward the understanding of the behavior of welded beam-column connections. The studies presented here and the others in this effort will prove valuable to the ultimate goal of developing well-founded, reliable means of predicting beam-column connection performance.

ACKNOWLEDGEMENTS

The large-scale beam-column connection tests were performed at the Earthquake Engineering Research Center of the University of California at Berkeley under the supervision of Professor Vitelmo Bertero and Dr. Andrew Whittaker. A detailed report on these tests can be found in "Technical Report: Experimental Investigations of Beam-Column Subassemblages", *Report No. SAC 96-01*, 1996. The analytical submissions were evaluated by a panel of three judges: Professor Helmut Krawinkler of Stanford University, Dr. Farzad Naeim of John A. Martin and Associates, and Professor Charles Roeder of the University of Washington. Their time and effort is greatly appreciated. James Malley, SAC Project Director of Topical Investigations, coordinated this activity.