SAC
Steel Project

Background
Document

The Impact of Earthquakes on Welded Steel Moment Frame Buildings: Experience in Past Earthquakes

Report No. SAC/BD-99/11

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
Paul B. Weinberg and James D. Goltz
EQE International

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

December 1999

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 documents part of the effort to document steel moment frame performance in the 1994 Northridge earthquake, and represents preliminary data on an array of economic, social and political issues. Specifically, an attempt was made to identify and collect relevant information on the economic, social and political impacts on owners, tenants, insurers, service-providers and regulatory agencies associated with the damaged steel frame buildings. This information includes losses and repair costs to owners and insurance companies as well as various indirect losses including lost rents and revenue, costs of mandatory inspection and code compliance, etc. Information on the welding, inspection and regulatory process was collected through a small number of in-depth interviews with contractors, inspectors and building officials. The documentation of the actions and decisions of the various parties affected by the earthquake damage will be helpful in the preparation of the guidelines and other documents.

Numerous individuals helped to review a preliminary version of this report, including members of the Past Performance Team, the Project Oversight Committee and representatives of FEMA. The contributions of these individuals are greatly appreciated.

The Impact of Earthquakes on Welded Steel Moment Frame Buildings: Experience in Past Earthquakes

Paul B. Weinberg
EQE, INTERNATIONAL

James D. Goltz
EQE, INTERNATIONAL

SUMMARY

In response to the unanticipated damage to over 200 welded steel moment frame (WSMF) buildings in the Northridge earthquake and the consequent need to revise building codes for this type of construction, a comprehensive program of research and evaluation was launched to address the many issues raised by the performance of these buildings.

The information reported in this document is part of the effort to document steel performance in past earthquakes and represents preliminary data on an array of economic, social and political issues. Specifically, an attempt was made to identify and collect relevant information on the economic, social and political impacts on owners, tenants, insurers, service providers and regulatory agencies associated with the damaged steel frame buildings. This information includes losses and repair costs to owners and insurance companies as well as various indirect losses including lost rents and revenue, costs of mandatory inspection and code compliance, etc. Information on the welding, inspection and regulatory process was collected through a small number of in-depth interviews with contractors, inspectors and building officials.

Clearly, the discovery of damage to WSMF buildings following the Northridge earthquake was the stimulus for a number of actions and decisions which have had, or will have, a tremendous impact on: the disciplines, professions and trades associated with steel construction; buildings codes, construction and inspection standards and practices; and, on seismic safety policy.

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