SAC
Steel Project

Background
Document

Development of Ground Motion Time Histories for Phase 2 of the FEMA/SAC Steel Project

Report No. SAC/BD-97/04

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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Woodward-Clyde Federal Services

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

October 15, 1997

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

One of the objectives of Phase II of the FEMA/SAC Steel Project is to develop performance-based guidelines for the seismic evaluation and design of steel moment frame structures. Key to the acceptance of such provisions is the quantification of the both the *capacity* of structural elements and systems and the *demands* imposed on these systems through structural response to strong ground motions. The focus of the series of analytical studies undertaken by the System Performance team is on the demand side of the equation – evaluating the influence of structural proportioning and configuration, connection hysteretic behavior, connection fracture, ground motion character and intensity, and other parameters on global (frame) and local (connection) response.

To fit within a reliability framework and be appropriate for implementation in United States building codes, the ground motions used for these analyses must be based on probablilistic estimates of seismic hazard appropriate to actual U.S. geographic regions. This report outlines the development of ground motions having various return periods (probabilities of exceedence) in three cities representing three different seismic zones as defined by the Uniform Building Code – Los Angeles, California (Zone 4); Seattle, Washington (Zone 3); and Boston, Massachusetts (Zone 2). The probabilities of exceedence are 10 percent in 50 years and 2 percent in 50 years; a set of motions for Los Angeles having a probability of exceedence of 50 percent in 50 years is also presented. All of these motions are for stiff soil sites and match (in the mean) the target response spectra defined in the 1994 NEHRP provisions.

Two additional sets of motions are developed for use in studies quantifying the influence of ground motion character on structural response. Soft soil acceleration time histories, calculated by propagating the 10 percent in 50 year records through six different soil profiles, are presented for each of the three cities, and a single set of near-fault ground motions (unscaled and not matched to any target spectra) are included to represent the observed scatter in actual deterministic recordings and numerical simulations.

The ground motion development effort was assisted by the Technical Advisory Panel for Ground Motion whose members included Norm Abrahamson, Jeff Kimball, and Geoff Martin. Art Frankel of the United States Geological Survey provided additional information. The contributions of these individuals is appreciated.

The time histories presented in this report are available to the public and may be downloaded from the World Wide Web at:

http://quiver.eerc.berkeley.edu:8080/studies/system/ ground-motions.html

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