



**Background
Document**

**The Effects of Connection Fractures on Steel Moment
Resisting Frame Seismic Demands and Safety**

Report No. SAC/BD-99/03

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>

July 1999

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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 System Performance team of the SAC Phase II Steel Project. This team was responsible for assessing the likely seismic demands on steel moment frames located in different hazard regions of the US. The team focused primarily on 3, 9 and 20 story steel frame buildings located in Los Angeles, Seattle and Boston (representative of regions of high, moderate and low seismic hazard). Local design professionals designed these structures based on pre-Northridge standards as well as on initial post-Northridge recommendations. System Performance team then carried out a wide range of nonlinear dynamic analyses to assess the sensitivity of seismic response to: The intensity and characteristics of ground motions, fracture of connections, deterioration of the hysteretic characteristics of plastic hinge regions, and the proportions and modeling idealizations utilized. In addition, the team evaluated results of dynamic response of frames incorporating partially restrained connections to assess their applicability to regions of moderate seismic risk. These studies were based on a set of ground motions developed for each city, consistent with current USGS hazard analyses corresponding to 50%, 10% and 2% probability of occurrence in 50 years.

This report focuses on studies undertaken related to the effect of brittle fracture on the seismic response of steel frame structures. Various random and deterministic approaches were taken to characterize the characteristics and spatial distributions of fractures. This project was performed at Stanford University in California. This task was identified as Task 5.4.6 of the SAC Phase II program.

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 System Performance; the Project Management Committee, and several members of the Project Oversight Committee. The contributions of these individuals are greatly appreciated.

The Effect of Connection Fractures on SMRF Seismic Demands and Safety

1. Contents, Approach, Models, and General Conclusions.....	1-1
1.1 Drift Demands.....	1-1
1.2 Methodology Developments.....	1-2
1.3 The Strategy in Selection of Cases.....	1-3
1.4 The Connection Fracture Model.....	1-4
1.5 Summary of Basic Results.....	1-5
2. Effect of Connection Fracture on Drift Demands.....	2-1
2.1 An Overview.....	2-1
2.2 Primary Drift Demand Results.....	2-3
2.3 Some Drift Demand Observations.....	2-4
2.4 Additional Sensitivity Studies and Observations.....	2-7
2.4.1 Fracture Parameter Variations.....	2-7
2.4.2 Distribution of Drifts Over Height.....	2-9
2.5 Special Studies.....	2-11
2.5.1 Severe Locations of Premature Fractures.....	2-11
2.5.2 The Effect of Interior Frames; The M1+ Model.....	2-13
2.5.3 Column Fractures at Connections.....	2-16
2.5.4 Soft-Soil Records.....	2-20
2.5.5 Near-Source Records.....	2-21
2.5.6 Number of Moment Resisting Frames (“Redundancy”).....	2-23
3. Methodology Developments.....	3-1
3.1 Annual Frequency of Drift Demand Exceedance: the Drift Demand Hazard Curve.....	3-1
3.1.1 Expected Drift versus Ground Motion Intensity.....	3-1
3.1.2 Drift Hazard Curves.....	3-4
3.1.3 Annual Frequency of Collapse and Other Drift Limit States.....	3-5
3.2 Dynamic Pushovers and Drift Capacity.....	3-6
3.3 Damaged Structure Analyses.....	3-7

Appendix A. Connection Fracture Models.....A-1

Appendix B. Drift Methodology Basis.....B-1
“Effects of Random Connection Fractures on the Demands and Reliability for a 3-
Story Pre-Northridge SMRF Structure”, Luco and Cornell, 6th USNCEE, Seattle,
Washington, June 1998.

Appendix C.....C-1
“Numerical Example of the Proposed SAC Procedure for Assessing the Annual
Exceedance Probabilities of Specified Drift Demands and of Drift Capacity”,
Luco and Cornell, Internal SAC Report, August, 1997.

**Appendix D. Calculation of Drift Demand Hazard and P_f when Some of the
Dynamic Analyses Fail to Converge.....D-1**

Appendix E. Tables of Record-by-Record Drift Results.....E-1

References.....R-1

Listing of SAC Reports.....S-1