

NIST GCR 10-917-9

Applicability of Nonlinear Multiple-Degree-of-Freedom Modeling for Design

NEHRP Consultants Joint Venture
*A Partnership of the Applied Technology Council and the
Consortium of Universities for Research in Earthquake Engineering*



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Prepared for
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Gaithersburg, Maryland*

By
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A Partnership of the Applied Technology Council and the
Consortium of Universities for Research in Earthquake Engineering

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Preface

The NEHRP Consultants Joint Venture is a partnership between the Applied Technology Council (ATC) and the Consortium of Universities for Research in Earthquake Engineering (CUREE). In 2007, the National Institute of Standards and Technology (NIST) awarded the NEHRP Consultants Joint Venture a National Earthquake Hazards Reduction Program (NEHRP) “Earthquake Structural and Engineering Research” task order contract (SB1341-07-CQ-0019) to conduct a variety of tasks. In 2008, NIST initiated Task Order 68241 entitled “Improved Nonlinear Static Seismic Analysis Procedures – Multiple-Degree-of-Freedom Modeling.” The purpose of this project was to conduct further studies on multiple-degree-of-freedom effects as outlined in the Federal Emergency Management Agency (FEMA) report, FEMA 440, *Improvement of Nonlinear Static Seismic Analysis Procedures* (FEMA, 2005).

The FEMA 440 Report concluded that current nonlinear static analysis procedures, which are based on single-degree-of-freedom (SDOF) models, are limited in their ability to capture the complex behavior of structures that experience multiple-degree-of-freedom (MDOF) response. It further concluded that improved nonlinear analysis techniques to more reliably address MDOF effects were needed. In response, work on this project was structured to include a detailed review of recent research on nonlinear MDOF modeling and the conduct of focused analytical studies to fill gaps in available information. This work was intended to improve nonlinear MDOF modeling for structural design practice by providing guidance on: (1) the minimum level of MDOF model sophistication necessary to make performance-based engineering decisions; (2) selection of appropriate nonlinear analysis methods; and (3) possible alternative approaches to analytical modeling.

The NEHRP Consultants Joint Venture is indebted to the leadership of Mike Valley, Project Director, and to the members of the Project Technical Committee, consisting of Mark Aschheim, Craig Comartin, William Holmes, Helmut Krawinkler, and Mark Sinclair, for their significant contributions in the development of this report and the resulting recommendations. Focused analytical studies were led by Mark Aschheim and Helmut Krawinkler, and conducted by Michalis Fragiadakis, Dimitrios Lignos, Chris Putman, and Dimitrios Vamvatsikos. Technical review and comment at key developmental stages on the project were provided by the Project Review Panel consisting of Michael Constantinou, Jerry Hajjar, Joe Maffei, Jack Moehle, Farzad Naeim, and Michael Willford. A workshop of invited experts was convened to obtain feedback on preliminary findings and recommendations, and input from this

group was instrumental in shaping the final product. The names and affiliations of all who contributed to this project are included in the list of Project Participants at the end of this report.

NEHRP Consultants Joint Venture also gratefully acknowledges Jack Hayes (Director, NEHRP) and Kevin Wong (NIST Technical Monitor) for their input and guidance in the preparation of this report and Ayse Hortacsu and Peter N. Mork for ATC report production services.

Jon A. Heintz
Program Manager

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