

# **ATC-29-1**

## **Proceedings of Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components**

**January 22-23, 1998  
San Francisco, California**

by

APPLIED TECHNOLOGY COUNCIL  
555 Twin Dolphin Drive, Suite 550  
Redwood City, CA 94065

Funded by

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH  
State University of New York at Buffalo  
Project 95-7202

and

NATIONAL SCIENCE FOUNDATION  
Washington, DC

### STEERING COMMITTEE

Christopher Rojahn, Co-Chairman  
T. T. Soong, Co-Chairman  
Christopher Arnold  
Robert E. Bachman  
Edwin T. Dean\*

Mircea Grigoriu  
Steven P. Harris  
Satwant S. Rihal  
William Staehlin  
Mahendra P. Singh

\*ATC Board Representative



---

# Preface

The ATC-29-1 Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components is the second seminar on this topic conducted by the Applied Technology Council (ATC). Similar to the 2-day ATC-29 seminar, which was held in Irvine, California, in October 1990, the purpose of the 1998 seminar is to present current research, practice, and informed thinking pertinent to seismic design, retrofit, and performance of nonstructural components. The seminar focus includes architectural, electrical, and mechanical components and their supports in buildings, hospitals and other essential facilities, and hazardous material and industrial facilities.

The seminar program has been developed for design professionals, regulators, researchers, manufacturers and contractors, insurers, owners, and facility managers. Included are 38 technical papers addressing the following topics:

- Observed performance in recent earthquakes;
- Seismic design codes, standards, and procedures for commercial and institutional buildings;
- Seismic design issues relating to industrial and hazardous material facilities;
- Design, analysis, and testing;

- Seismic evaluation and rehabilitation of conventional and essential facilities (including hospitals)

ATC gratefully acknowledges the Steering Committee, who planned the seminar, and the numerous professionals, who prepared papers for the seminar. The Steering Committee consisted of Christopher Rojahn and Tsu T. Soong (co-chairs), Christopher Arnold, Robert E. Bachman, Edwin T. Dean (ATC Board Representative), Mircea Grigoriu, Steven P. Harris, Satwant S. Rihal, William E. Staehlin, and Mahendra P. Singh. The affiliations of the Steering Committee members are provided in the list of project participants. Paper authors and their affiliations are included with each paper.

ATC also gratefully acknowledges the financial support provided by the National Center for Earthquake Engineering Research and the National Science Foundation. The seminar logistics and report preparation services of ATC staff are also greatly appreciated.

Christopher Rojahn  
Executive Director



---

# Contents

PREFACE .....	iii
INTRODUCTION .....	1
SEMINAR TECHNICAL PAPERS .....	5
Building Code Seismic Design Provisions for Nonstructural Components (Invited Paper), Robert Bachman .....	7
Design Criteria for Nonstructural Components Based on Tri-Services Manuals, Sigmund A. Freeman .....	15
The Development of Model Code Provisions to Address System Reliability Following Earthquakes, Gayle S. Johnson, Stephen J. Eder, Robert E. Sheppard, and Steven P. Harris .....	31
Simplified Methods for Calculating Seismic Forces for Nonstructural Components, Mahendra P. Singh, Luis M. Morechi, and Luis E. Suarez .....	43
A Critique of Procedures for Calculating Seismic Design Forces for Nonstructural Elements, Brian E. Kehoe and Sigmund A. Freeman.....	57
Review of Requirements for Design of Nonstructural Components and Their Anchorage, Orhan Gurbuz, Sheng Wu, and Scott Wittchen .....	71
A Suggested Design Procedure for Piping Systems Defined as Hazardous or Essential by U.S. Building Codes, John D. Stevenson.....	79
Lessons Learned from the 1994 Northridge Earthquake on the Vulnerability of Nonstructural Systems, William E. Gates and Gary McGavin .....	93
Performance of Nonstructural Components During the January 17, 1994 Northridge Earthquake, Case Studies of Six Instrumented Multistory Buildings, Farzad Naeim and Roy Lobo .....	107
Performance and Behavior of Library Shelving and Storage Rack Systems During the 1994 Northridge Earthquake, Satwant S. Rihal and William E. Gates .....	121
The Need for Improvement in Post-Earthquake Investigations of the Performance of Nonstructural Components (Invited Paper), Robert Reitherman .....	137
Retrofit Seismic Mitigation of Mainframe Computers and Associated Equipment: A Case Study, John D. Meyer, Tsu T. Soong, and Richard H. Hill .....	149
Frequency Tuning for Spring-Supported Mechanical Components' Protection, George C. Yao and N. Lien .....	165

Upper-Bound Mass Ratios for the Decoupled Analysis and Design of Building-Equipment System, Genda Chen, and Jingning Wu .....	173
Simplified Approach to Account for Nonlinear Effects in Seismic Analysis of Nonstructural Components, Roberto Villaverde.....	187
Seismic Retrofit of Precast Concrete Connections, Richard J. Nielsen, Edwin R. Schmeckpeper, and Richard Crossler.....	201
Simplifying Complex GFRC Cladding Structural Systems in Seismic Hazard Zones: A Case Study, Michael Krakower, Milford W. Donaldson, and Anthony B. Court .....	215
Limit States for Architectural Glass Under Simulated Seismic Loadings, Richard A. Behr and Christy L. Worrell.....	229
Seismic Evaluation Procedure for Equipment in U. S. Department of Energy Facilities (Invited Paper), Robert C. Murray, Stanley Sommer, Fred Loceff, George Antaki, Gary Driesen, Dan Guzy and Jeffrey Kimball .....	241
Computer Tools for Seismic Screening and Evaluation of Equipment and Systems Based on Earthquake Experience Data, Thomas R. Roche, Phillip S. Burtis and Ronald W. Cushing.....	255
Earthquake-Caused Hazardous Materials Incidents at Educational Facilities, Guna Selvaduray.....	265
City of Los Angeles Proposed Ordinance Changes for Suspended Ceiling Systems Prompted by the 1994 Northridge Earthquake, Gary L. McGavin, James Lai and Steve Ikkanda .....	277
Seismic Restraints for Piping and Duct Systems, Robert J. Wasilewski .....	283
Seismic Isolation of Semiconductor Production Facilities, Hal Amick, Ahmad Bayat and Zoltan A. Kemeny .....	297
The Use of Earthquake Experience Data for Estimates of the Seismic Fragility of Standard Industrial Equipment, Sam W. Swan and Robert Kassawara.....	313
Toppling Fragility of Unrestrained Equipment, Z. Y. Zhu and T. T. Soong.....	323
Seismic Reliability and Performance of Nonstructural Systems, M. Grigoriu and F. Waisman .....	337
Demonstration of CERL Equipment Fragility and Protection Procedure by Fragility Testing of a Power Transformer Bushing, James Wilcoski .....	349
California Wine Industry Seismic Risk Analysis and Experimentation Project, Joshua M. Marrow, David Weggel, Abraham Lynn and Satwant Rihal.....	365
Study of Seismic Resistance of Desktop Computers, Masami Jin and Abolhassan Astaneh-Asl.....	379

Appropriate Seismic Reliability for Critical Equipment Systems: An Approach Based on Regional Analysis of Financial and Life Loss, Keith A. Porter and Charles Scawthorn .....	393
Development and Usage of FEMA 74, Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide, Eduardo A. Fierro and Cynthia L. Perry .....	421
The Requirements for Nonstructural Components for the NEHRP Guidelines for the Seismic Rehabilitation of Buildings, Christopher Arnold .....	433
Practical Guidelines for Seismic Retrofitting of HVAC Systems, Patrick J. Lama .....	445
Observed Behavior of Italian Hospitals During Severe Earthquakes, G. Di Pasquale, C. Nuti, G. Orsini, and T. Sano .....	455
Seismic Design and Performance of Nonstructural Components in Hospitals (Invited Paper), William Staehlin .....	469
Seismic Retrofit of Nonstructural Components in Acute Care Hospitals: Title 24, Part 2, Chapter 16, Division III-R Requirements, Charles C. Thiel Jr., Theodore C. Zsutty, Christos Tokas and Patrick Campbell.....	475
The Benefits and Costs of Seismic Retrofits of Nonstructural Components for Hospitals, Essential Facilities and Schools, John Eidinger and Kenneth Goettel .....	491
ATC-29-1 PROJECT PARTICIPANTS .....	505
APPLIED TECHNOLOGY COUNCIL PROJECTS AND REPORT INFORMATION .....	507