

## **G. LIST OF RESOURCES RELATED TO NONSTRUCTURAL COMPONENTS**

This appendix is a list of available resources related to nonstructural components, including codes and standards, testing protocols, guidance documents, nonproprietary details, photos, sample specifications, proprietary details, products, and research efforts. This list originates from Appendix B of the ATC-69 Report, *Reducing the Risks of Nonstructural Earthquake Damage, State-of-the-Art and Practice Report*, prepared by the Applied Technology Council for FEMA (ATC, 2008).

The information in this appendix is organized into the following tables:

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**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ACI 318-08	Building Code Requirements for Reinforced Concrete and Commentary	2008	Appendix D	Appendix on requirements for anchorage in concrete; published by the American Concrete Institute, Detroit, Michigan.
ACI 355.2-07	Qualification of Post-Installed Mechanical Anchors in Concrete	2007		Published by the American Concrete Institute, Detroit, Michigan.
ASCE/SEI 7-05	Minimum Design Loads for Buildings and Other Structures	2005	Chapter 13	Chapter specifying seismic design requirements for nonstructural components; published by the American Society of Civil Engineers, Reston, Virginia.
SEI/ASCE 31-03	Seismic Evaluation of Existing Buildings	2003	Sections 3.9, 4.2.7, 4.8, and Table 4-9	Successor document to FEMA 310 <i>Handbook for the Seismic Evaluation of Buildings – A Prestandard</i> . Relevant sections describe evaluation procedures for existing nonstructural components. Includes comprehensive checklists of potential nonstructural hazards. Published by the American Society of Civil Engineers, Reston, Virginia.
ASCE/SEI 41-06	Seismic Rehabilitation of Existing Buildings	2007	Chapter 11	Successor document to FEMA 356 <i>Prestandard and Commentary for the Seismic Rehabilitation of Buildings</i> . Relevant chapter describes design procedures for the rehabilitation of existing nonstructural components, and a table identifying nonstructural component types and their applicability to different performance objectives. Published by the American Society of Civil Engineers, Reston, Virginia.

**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ASCE/SEI 43-05	Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities	2005		Provides design criteria for structures, systems, and components in nuclear facilities, with the goal of ensuring that these facilities can withstand the effects of earthquake ground shaking at the desired level of performance. Published by the American Society of Civil Engineers, Reston, Virginia.
ASHRAE SPC 171P	Method of Test of Seismic Restraint Devices for HVAC&R Equipment	2006		Establishes methods of testing and documenting the working shear and tensile strength of seismic restraint devices that are integral with vibration isolators or resilient devices. Published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
ASTM E580/ E580M-06	Standard Practice for Application of Ceiling Suspension Systems for Acoustical Tile and Lay-In Panels in Areas Requiring Seismic Restraint	2006		Standard for Zone 2; could also be used for Zones 3 and 4. Published by ASTM International, West Conshohocken, Pennsylvania.
Bulletin 2004-014-BU  (Vancouver)	Seismic Restraint of Nonstructural Components	2004		Addresses suspended ceilings and non-load bearing partitions. Published by the City of Vancouver, British Columbia.

**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
CSA S832-06 (Canada)	Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings	2006		Operational and functional components (OFCs) is a Canadian term for nonstructural components. The second edition of a document first published in 2001. Describes how to identify and evaluate hazards caused by nonstructural components, and provides strategies to mitigate damage. Intended to be applicable to most buildings types, either new or existing, and intended for building owners, inspectors, facility managers, engineers, architects and others whose focus is to provide safety, serviceability and durability of nonstructural components when subjected to earthquakes. Published by the Canadian Standard Association, Mississauga, Ontario.
E.030 (Peru)	National Construction Code, Technical Standard for Buildings, E.030 Earthquake-Resistant Design	2003		Design requirements for buildings in Peru. Drift provisions changed in 1997, and are now among the most stringent in the world. Drift must be computed without an R factor, and allowable drift is limited to .007h for reinforced concrete, and .01h for steel structures. Standard school construction must be confined concrete, and masonry infill must be isolated from the concrete frame. Schools built since 1997 meeting these criteria have suffered virtually no damage in recent large earthquakes in Peru. Published by El Servicio Nacional de Normalización, Capacitación e Investigación para la Industria de la Construcción (SENCICO), Lima, Perú.

**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
EN 1998-1:2004(E) (Europe)	Eurocode 8: Design of Structures For Earthquake Resistance (English version, Final Draft)	2004	Part 1, Sections 4.3.5, 4.3.6	Includes general rules, seismic actions, and rules for buildings. Relevant sections cover design of nonstructural elements and additional measures for masonry infilled frames. Non-structural elements mentioned include parapets, gables, antennae, mechanical appendages and equipment, curtain walls, partitions, and railings. Nonstructural elements that might cause risks to persons, affect the main structure, or disrupt services of critical facilities must be verified to resist seismic design actions. Designs for nonstructural elements of great importance are based on realistic models of the structure and on appropriate response spectra derived from the response of the supporting structural elements. Lateral force calculations include consideration of period ratio, importance factor, and behavior factor. Published by the European Committee for Standardization (CEN).
IBC 2006	2006 International Building Code	2006		National model building code, latest edition; scheduled for adoption in most jurisdictions across the United States. Specifically references ASCE 7-05 for design of nonstructural components. Published by the International Code Council, Washington, D.C.
IBC 2003	2003 International Building Code	2003		National model building code; adopted in some areas of the United States. Published by the International Code Council, Washington, D.C.

**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ICC-ES AC-156	Acceptance Criteria for Seismic Qualification by Shake-Table Testing of Nonstructural Components and Systems.	2004		Published by the International Code Council Evaluation Service, Whittier, California.
NFPA 13	Standard for the Installation of Sprinkler Systems, 2007 Edition	2007		Published by the National Fire Protection Association, Quincy, Massachusetts.
NCh 433.Of96 (Chile)	Chilean Norm NCh 433.Of96, Earthquake Resistant Design of Buildings	1996		Chilean code for buildings. Includes the following drift criteria: (1) drift must be computed without an R factor; and (2) must be less than 0.002h for buildings with precast shear walls with dry joints; less than 0.003h for shear wall building with rigidly attached masonry infill; less than .0075h for unbraced frames with isolated infill; and less than .015h for other structures. Includes a scale factor $Q/Q_{min}$ that allows a reduction of the computed drift for longer period structures where the design base shear Q is less than a minimum base shear $Q_{min}$ . Stringent drift criteria (more stringent than U.S. codes) have resulted in an almost exclusive use of shear wall systems in buildings. As a result, drift-related nonstructural damage is significantly reduced. Published by the Instituto Nacional de Normalizacion (INN-Chile), Santiago, Chile.

**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
NCh 2369.Of2003 (Chile)	Chilean Norm NCh2369, Earthquake Resistant Design of Industrial Structures and Facilities	2003		Chilean code for industrial buildings. Includes recommendations and design rules for mechanical equipment that could be applicable to other types of buildings. Currently only available in Spanish. Published by the Instituto Nacional de Normalizacion (INN-Chile), Santiago, Chile.
UBC 1961	Uniform Building Code, 1961 Edition	1961		First appearance of separate provisions for nonstructural components in the UBC; maximum lateral force of 0.2g in Zone 3.
UBC 1976	Uniform Building Code, 1976 Edition	1976		Nonstructural provisions updated in response to 1971 San Fernando Earthquake; maximum force increased to 0.3g in Zone 4.
UBC 1988	Uniform Building Code, 1988 Edition	1988		Update of nonstructural provisions to consider response of non-rigid items and items at grade; maximum force remained 0.3g in Zone 4 for rigid items.
UBC 1997	Uniform Building Code, 1997 Edition	1997		Nonstructural seismic requirements are a blend of requirements from the 1994 and 1997 <i>NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures</i> .
USACE TI 809-04	Tri-Service Manual, Seismic Design for Buildings	1998	Chapter 10	Successor document to TM 5-809-10 and TM 5-809-10-1. Published by the US Army Corps of Engineers, Washington, D.C.

**Table G-1 Codes and Standards Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
USACE TM 5-809-10	Tri-Service Manual, Seismic Design for Buildings	1996	Chapter 8, Appendix L	Provides a dynamic analysis procedure for design of nonstructural components that must remain functional after a major earthquake. Requires generation of floor response spectra and consideration of inter-story drift at the location of essential equipment. Appendix includes four design examples. Published by the US Army Corps of Engineers, Washington, D.C.
USACE TM 5-809-10-1	Tri-Service Manual, Seismic Design Guidelines for Essential Buildings	1986	Chapter 6	Provides methodology for design; defines essential nonstructural systems (Table 6-3); defines two levels of earthquake ground motion (EQ-I and EQ-II); requires equipment certification. Published by the US Army Corps of Engineers, Washington, D.C.
USACE TM-5-809-10-2	Tri-Service Manual, Seismic Design Guidelines for Upgrading Existing Buildings	1988	Chapter 9	Chapter focuses on improving performance of existing nonstructural installations. Includes a list of nonstructural systems with descriptions of potential damage and failure modes (Table 9-1). Published by the US Army Corps of Engineers, Washington, D.C.
VISCMA 102-07	Static Qualification Standards for Obtaining a VISCMA Compliant Seismic Component Rating	2007		Testing protocol for mechanical, electrical and plumbing equipment. Published by the Vibration Isolation and Seismic Control Manufacturers Association, Wayne, Pennsylvania.



**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ASHRAE RP-812	A Practical Guide to Seismic Restraint	1999		Published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
ASHRAE /SMACNA	Seismic Restraint Applications CD-ROM	2002		Provides technical information for design and installation of seismic restraints for HVAC equipment, piping, and ducts. Includes representative bracing details, layout examples, and tables. Consists of portions of the following documents: SMACNA's Seismic Restraint Manual: Guidelines for Mechanical Systems; ASHRAE's Handbook - HVAC Applications (2003); and ASHRAE's A Practical Guide to Seismic Restraint. Produced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. and the Sheet Metal and Air Conditioning Contractors' National Association.
CISCA 1991	Recommendations for Direct-Hung Acoustical and Lay-in Panel Ceilings, Seismic Zones 0-2	1991		Industry standards for ceilings in low seismic zones. Published by Ceilings and Interior Systems Construction Association, Deerfield, Illinois.
CISCA 1990	Recommendations for Direct-Hung Acoustical and Lay-in Panel Ceilings, Seismic Zones 3-4	1990		Industry standards for ceilings in high seismic zones. Published by Ceilings and Interior Systems Construction Association, Deerfield, Illinois.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
DGS, DSA (California )	Guide and Checklist for Nonstructural Earthquake Hazards in California Schools			Identifies potential hazards associated with nonstructural components and provides recommendations to mitigate hazards. Includes typical details and a nonstructural earthquake hazards checklist. Published by the California State Department of General Services, Division of the State Architect, and the Governor’s Office of Emergency Services, Sacramento, California.
DOISSP	Nonstructural Hazards Rehabilitation Guidelines; Vol. I; Guidelines Usage, Architectural, Mechanical, Electrical, Plumbing			Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.
DOISSP	Nonstructural Hazards Rehabilitation Guidelines; Vol. II; Furnishings, Interior Equipment, Miscellaneous Components, Mobile Homes, Manufactured Homes, FEMA 273, FEMA 310, FEMA 178, & ASCE 31-			Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
	xx Excerpts			
EERI 84-04	Nonstructural Issues of Seismic Design and Construction	1984		Results of workshop including invited papers on nonstructural issues. Published by the Earthquake Engineering Research Institute, Oakland, California.
FEMA	Instructor's Guide for Nonstructural Earthquake Mitigation for Hospitals and other Health Care facilities.	1988		Materials for course given by Emergency Management Institute, Emmitsburg, Maryland.
FEMA	Final Report, Nonstructural Earthquake Mitigation Guidance Manual.	2004		Based on FEMA Region X Earthquake Hazard Mitigation Handbook for Public Facilities, 2002. Includes flowcharts, step-by-step procedures and some details. Divides nonstructural components into four groups: contents, exterior building elements, interior building elements, and building utilities. Prepared by URS Group, Inc. for FEMA.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA Region X	Earthquake Hazard Mitigation Handbook for Public Facilities	2002		Available at <a href="http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm">http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm</a>
FEMA 74	Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide. Third Edition	1994		Successor document to previous editions of FEMA 74, first published in 1985.
FEMA 74-FM	Earthquake Hazard Mitigation for Nonstructural Elements, Field Manual	2005		Includes three types of details: Non-Engineered, Prescriptive, and Engineered. Contains more details than FEMA 74, along with a field data sheet based on the FEMA 74 checklist.
FEMA 150	Seismic Considerations: Health Care Facilities	1990		Published by the Federal Emergency Management Agency, Washington, D.C.
FEMA 172	NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings	1992	Chapters 5, 6	Relevant chapters include details for electrical cabinets, chimneys, parapets, masonry partitions, raised access floors, and mechanical equipment.
FEMA 178	NEHRP Handbook for the Seismic Evaluation of Existing	1992	Section 10.5	Predecessor document to FEMA 310.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
	Buildings			
FEMA 232	Homebuilders' Guide to Earthquake-Resistant Design and Construction	2006		Includes details based on the 1994 edition of FEMA 74.
FEMA 273	NEHRP Guidelines for the Seismic Rehabilitation of Buildings	1997		Predecessor document to FEMA 356.
FEMA 310	Handbook for the Seismic Evaluation of Buildings - A Prestandard	1998	Sections 3.9, 4.2.7, 4.8, and Table 4-9	Predecessor document to SEI/ASCE 31-03. Relevant sections describe evaluation procedures for existing nonstructural components. Includes comprehensive checklists of potential nonstructural hazards.
FEMA 356	Prestandard and Commentary for the Seismic Rehabilitation of Buildings	2000	Chapter 11	Successor document to FEMA 273/274, and predecessor to ASCE/SEI 31-03. Relevant chapter describes design procedures for the rehabilitation of existing nonstructural components, and a table identifying nonstructural component types and their applicability to different performance objectives.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 389	Communicating with Owners and Managers of New Buildings on Earthquake Risk: A Primer for Design Professionals	2004		
FEMA 395	Incremental Seismic Rehabilitation of School Buildings (K-12): Providing Protection to People and Buildings	2003		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-21) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to school occupancies.
FEMA 396	Incremental Seismic Rehabilitation of Hospital Buildings: Providing Protection to People and Buildings	2003		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-23) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to hospital occupancies.
FEMA 397	Incremental Seismic Rehabilitation of Office Buildings: Providing Protection to People and Buildings	2003		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-24) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to office occupancies.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 398	Incremental Seismic Rehabilitation of Multifamily Apartment Buildings: Providing Protection to People and Buildings	2004		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-22) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to multifamily apartment occupancies.
FEMA 399	Incremental Seismic Rehabilitation of Retail Buildings: Providing Protection to People and Buildings	2004		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-22) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to retail occupancies.
FEMA 400	Incremental Seismic Rehabilitation of Hotel and Motel Buildings	2005		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-23) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to hotel and motel occupancies.
FEMA 412	Installing Seismic Restraints for Mechanical Equipment	2002		Includes numerous elaborate details and many recommendations for seismic restraint of mechanical equipment.
FEMA 413	Installing Seismic Restraints for Electrical Equipment	2004		Includes numerous elaborate details and many recommendations for seismic restraint of electrical equipment.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 414	Installing Seismic Restraints for Duct and Pipe	2004		Includes numerous elaborate details and many recommendations for seismic restraint of duct and piping components.
FEMA 424	Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds	2004		Includes pictures of nonstructural damage (pages 4-17 through 4-19, 4-23, 4-24, 4-30, 4-31); a list of types of nonstructural components (page 4-59); graphics for ceilings, shelves, and walls (pages 4-60 and 4-61).
FEMA 433	Using HAZUS-MH for Risk Assessment: How-To Guide	2004		
FEMA 445	Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings	2006	Section 4.2	Describes how performance-based seismic design guidelines will be developed under the ATC-58 Project. Section 4.2 refers specifically to the development of nonstructural performance products.
FEMA 450	NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Part 1 and 2: Provisions and Commentary	2004	Chapters 6, 6A, and Commentary	Provides criteria for the design and construction of structures to resist earthquake ground motions. Relevant chapters include prescriptive requirements for the design of architectural, mechanical, electrical and piping components.



**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 452	A How-To Guide to Mitigate Potential Terrorist Attacks Against Buildings	2005		
FEMA 454	Designing for Earthquakes: A Manual for Architects	2006	Section 6.6, Chapter 9	Discussion of code issues including nonstructural issues. Contains a collection of photos and generic details borrowed from various sources including: FEMA 74; details developed for the Lawrence Livermore National Lab; and the SMACNA Guidelines. Includes a discussion on the need for systems engineering, considering all parts of the building as a whole. Provides a checklist (Table 9-3) showing allocation of design responsibilities for nonstructural systems and components.
FEMA 460	Seismic Considerations for Steel Storage Racks Located in Areas Accessible to the Public	2005		Includes: a review of the performance of storage racks in past earthquakes; a history of the development of codes and standards used for storage rack design; current storage rack design practices; guidance on recommended performance goals and design requirements for storage racks; guidelines for implementation/responsibilities associated with the specification, procurement, and installation of pallet storage racks; suggested guidance for securing contents; recommendations for operations and use; suggested guidance for quality assurance programs; a discussion of current and past storage rack research and testing; suggestions for post-earthquake inspections; and proposed modifications to seismic

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
				design provisions and standards for racks.
FEMA 461	Interim Protocols for Determining Seismic Performance Characteristics of Structural and Nonstructural Components	2007		Provides an interim protocol for testing of building components to establish their performance capability in the form of fragility functions. Fragility functions are used to assess the seismic performance of individual components, systems incorporating these components, and buildings containing these systems and components that are subjected to earthquake shaking. Protocols are not intended for seismic performance qualification testing of nonstructural components required by the building code, although the loading protocols could be used for that purpose.
FEMA 577	Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and	2007		

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
	Buildings			
FEMA 582	Design Guide for Improving Commercial Buildings Safety in Earthquakes, Floods, and High Winds	Future		
John Wiley & Sons, Inc.	Earthquakes, an Architect's Guide to Nonstructural Seismic Hazards	1990		Target audience is architects. Written by H.J. Lagorio. Published by John Wiley & Sons, Inc., New York, New York.
OCIPEP (Canada)	Seismic Hazard Assessment and Mitigation for Buildings' Functional and Operational Components: A Canadian Perspective	2002		Contains figures and photos from various sources, including FEMA 74. Includes damage photos from 1999 Chi Chi, Taiwan Earthquake: damage to rooftop equipment (page 19); collapse of free-standing non-structural wall (page 20); and damage to sprinkler systems. Prepared by the Department of Civil Engineering, University of Ottawa, for the Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP), Ontario, Canada.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
Oregon Emergency Management	Earthquake Preparedness and Mitigation Guidance for Oregon State Agency Offices and Warehouses	2004		Focuses on office and warehouse occupancies, with special attention to storage racks. Includes photos and guidance including shrink-wrap and netting to mitigate potential falling hazards. Provides some specific information on performance of furniture by specific vendors (Hayworth, Steelcase, and Artmet).
Pan American Health Organization	Principles of Disaster Mitigation in Health Facilities	2000	Chapter 3	Includes guidance on assessing and mitigating seismic vulnerabilities of nonstructural components. Published by the Pan American Health Organization, Regional Office of the World Health Organization, Washington, D.C.
Salt Lake City School District	Seismic Design Criteria of Nonstructural Systems For New School Facilities And Existing School Facilities	2001		Developed under a FEMA "Project Impact" Grant. Intended for use on new school design projects and seismic retrofit projects in the Salt Lake City School District. Establishes minimum design procedures, general detailing requirements, design approval procedures, and construction inspection procedures for nonstructural items. The design engineer or architect is responsible for development of project specific nonstructural details. Some requirements exceed the minimum standards given in the Uniform Building Code (UBC).
Seattle Public Schools	School Facilities Manual: Nonstructural Protection Guide. Safer Schools, Earthquake Hazards, Nonstructural. Second	2000		Includes detailed inventory form and details not included in FEMA 74.

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
	Edition			
University of California, Berkeley	UC Berkeley: Q-Brace Quake Bracing Guidelines	2005		Guidelines developed for University of California, Berkeley campus facilities. Includes detailed solutions for contents identifying vendor supplied products or size of hardware to use.
USACERL TR-98/34	Seismic Mitigation for Equipment at Army Medical Centers	1998		Presents simple methods for reducing the seismic vulnerability of equipment at Army medical centers. Illustrations, observations, and recommendations are based on examples from Madigan Army Medical Center (MAMC). Concerns about particular well-anchored critical medical equipment are presented. Published by the U.S. Army Construction Engineering Research Laboratories.
USACE, Engineering and Support Center	Seismic Protection for Mechanical Equipment			Presentation on procedures to design seismic supports of equipment, piping, and ducts; includes force coefficients and methods to calculate forces. Also includes a list of references useful as guidelines for the design. Available from the U.S. Army Corps of Engineers at <a href="http://www.dtic.mil/ndia/2005triservice/track16/stut.pdf">http://www.dtic.mil/ndia/2005triservice/track16/stut.pdf</a> .

**Table G-2 Guidance Documents Related to Nonstructural Components (continued)**

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
VISCMA	Understanding the 2000 IBC Code (Architectural Components and Equipment Restraint)	2005		Available on the Vibration Isolation and Seismic Control Manufacturers Association website at <a href="http://www.viscma.com/articles.htm">http://www.viscma.com/articles.htm</a>
VISCMA	The Pitfalls of Combining Internal & External Equipment Isolation	2003		Explains problems associated with utilizing both internal and external isolation in equipment. Shows that performance is better if only external isolation is used. Available on the Vibration Isolation and Seismic Control Manufacturers Association website at <a href="http://www.viscma.com/articles.htm">http://www.viscma.com/articles.htm</a>

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
ASHRAE /SMACNA	Non-proprietary Details	Seismic Restraint Applications CD-ROM	2002		Provides technical information for design and installation of seismic restraints for HVAC equipment, piping, and ducts. Includes representative bracing details, layout examples, and tables. Consists of portions of the following documents: SMACNA's Seismic Restraint Manual: Guidelines for Mechanical Systems; ASHRAE's Handbook - HVAC Applications (2003); and ASHRAE's A Practical Guide to Seismic Restraint. Produced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. and the Sheet Metal and Air Conditioning Contractors' National Association.
ATC-38	Damage Inventory Form	ATC-38 Postearthquake Building Performance Assessment Form and Surveyor Instructions	2001		10-page form and instructions that provides standardized damage percentages and standardized codes for ceilings and partitions. Available with the ATC-38 Project report, or on the EERI website at <a href="http://www.eeri.org/">http://www.eeri.org/</a>
Dartmouth College	Sample Specification	Dartmouth College Design & Construction Guidelines, Section 15240  Seismic Restraint and Vibration Control	2004		Specification for the installation of equipment at Dartmouth College. Available at <a href="http://www.dartmouth.edu/~opdc/pdfs/15240.pdf">http://www.dartmouth.edu/~opdc/pdfs/15240.pdf</a>

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
DGS, DSA (California )	Guide and Checklist	Guide and Checklist for Nonstructural Earthquake Hazards in California Schools	2003		Identifies potential hazards associated with nonstructural components and provides recommendations to mitigate hazards. Includes typical details and a nonstructural earthquake hazards checklist. Published by the California State Department of General Services, Division of the State Architect, and the Governor’s Office of Emergency Services, Sacramento, California.
DOISSP	Non-proprietary Details	Nonstructural Hazards Rehabilitation Guidelines; Vol. I; Guidelines Usage, Architectural, Mechanical, Electrical, Plumbing	2003		Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.
DOISSP	Non-proprietary Details	Nonstructural Hazards Rehabilitation Guidelines; Vol. II; Furnishings, Interior Equipment, Miscellaneous Components, Mobile Homes, Manufactured Homes, FEMA 273,	2003		Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.



**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
		FEMA 310, FEMA 178, & ASCE 31-xx Excerpts			
EERI	Damage Inventory Form	EERI Reconnaissance/ Clearinghouse Report Form - Architectural and Nonstructural Elements	2000		2-page form consisting of broad categories, several subcategories, and blank lines to report damage and gather damage statistics.
FEMA	Non-proprietary Details	Final Report, Nonstructural Earthquake Mitigation Guidance Manual	2004		Based on FEMA Region X Earthquake Hazard Mitigation Handbook for Public Facilities, 2002. Includes flowcharts, step-by-step procedures and some details. Divides nonstructural components into four groups: contents, exterior building elements, interior building elements, and building utilities. Prepared by URS Group, Inc. for FEMA.

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
FEMA Region X	Non-proprietary Details	Earthquake Hazard Mitigation Handbook for Public Facilities	2002		Available at <a href="http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm">http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm</a>
FEMA 74	Non-proprietary Details	Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide. Third Edition	1994		Successor document to previous editions of FEMA 74, first published in 1985.
FEMA 74 FM	Non-proprietary Details	FEMA 74 Field Manual	2005		Includes three types of details: Non-Engineered, Prescriptive, and Engineered. Contains more details than FEMA 74, along with a field data sheet based on the FEMA 74 checklist.
FEMA 172	Non-proprietary Details	NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings	1992	Chapters 5, 6	Relevant chapters include details for electrical cabinets, chimneys, parapets, masonry partitions, raised access floors, and mechanical equipment.
FEMA 412	Non-proprietary Details	Installing Seismic Restraints for Mechanical Equipment	2002		Includes numerous elaborate details and many recommendations for seismic restraint of mechanical equipment.

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
FEMA 413	Non-proprietary Details	Installing Seismic Restraints for Electrical Equipment	2004		Includes numerous elaborate details and many recommendations for seismic restraint of electrical equipment.
FEMA 414	Non-proprietary Details	Installing Seismic Restraints for Duct and Pipe	2004		Includes numerous elaborate details and many recommendations for seismic restraint of duct and piping components.
FEMA 424	Photos, Damage	Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds	2004		Includes pictures of nonstructural damage (pages 4-17 through 4-19, 4-23, 4-24, 4-30, 4-31); a list of types of nonstructural components (page 4-59); graphics for ceilings, shelves, and walls (pages 4-60 and 4-61).
FEMA 454	Non-proprietary Details	Designing for Earthquakes: A Manual for Architects	2006	Section 6.6, Chapter 9	Discussion of code issues including nonstructural issues. Contains a collection of photos and generic details borrowed from various sources including: FEMA 74; details developed for the Lawrence Livermore National Lab; and the SMACNA Guidelines. Includes a discussion on the need for systems engineering, considering all parts of the building as a whole. Provides a checklist (Table 9-3) showing allocation of design responsibilities for nonstructural systems and components.

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
Los Alamos National Laboratory	Sample Specification	Section 22 0548 Vibration and Seismic Controls for Plumbing, Piping, and Equipment	2006		Specification for the anchorage of equipment at Los Alamos National Lab. Available at <a href="http://engstandards.lanl.gov/conspec/pdf/22_0548R0.pdf">http://engstandards.lanl.gov/conspec/pdf/22_0548R0.pdf</a>
OCIPEP (Canada)	Photos, Damage	Seismic Hazard Assessment and Mitigation for Buildings' Functional and Operational Components: A Canadian Perspective	2002		Contains figures and photos from various sources, including FEMA 74. Includes damage photos from 1999 Chi Chi, Taiwan Earthquake: damage to rooftop equipment (page 19); collapse of free-standing non-structural wall (page 20); and damage to sprinkler systems. Prepared by the Department of Civil Engineering, University of Ottawa, for the Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP), Ontario, Canada.
Oregon Emergency Management	Non-proprietary Details	Earthquake Preparedness and Mitigation Guidance for Oregon State Agency Offices and Warehouses	2004		Focuses on office and warehouse occupancies, with special attention to storage racks. Includes photos and guidance including shrink-wrap and netting to mitigate potential falling hazards. Provides some specific information on performance of furniture by specific vendors (Hayworth, Steelcase, and Artmet).

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
PEER 2003/05	Taxonomy and Nonstructural Damage Inventory Form	Response Assessment of Nonstructural Building Elements	2003		Proposes a taxonomy (classification) of nonstructural elements by functionality, modes of failure, acceleration-sensitive or drift-sensitive response parameter, and repercussions of damage. Provides damageability, cost, and loss data for 200 elements. Includes a Nonstructural Damage Inventory Form used following the Nisqually Earthquake.
PEER 2003/12	Non-proprietary Details	Implementation Manual for the Seismic Protection of Laboratory Contents: Format and Case Studies	2003		Presents case studies for University of California Berkeley campus labs. Suggests format for User's Manual that could be used to help occupants install do-it-yourself details for a particular facility.
PEER 2005/03	Taxonomy	A Taxonomy of Building Components for Performance-Based Earthquake Engineering	2005		Provides a detailed taxonomy (classification) of nonstructural components. Each component is assigned a unique identification number. The list differentiates between anchored and unanchored versions of the same item.
Sandia	Sample Specification	Special Specification Section 13085S - Seismic Protection			Sample specification for the anchorage of equipment at Sandia (16 pages). Includes lists of equipment, detailed requirements, specific instructions for some items, load limits, and member sizes.

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
Seattle Public Schools	Non-proprietary Details	School Facilities Manual: Nonstructural Protection Guide. Safer Schools, Earthquake Hazards, Nonstructural. Second Edition	2000		Includes detailed inventory form and details not included in FEMA 74.
Southern California Earthquake Center	Photos, Damage	Nonstructural Issues in Public Schools - "Stairs to Nowhere"	2000		Photos of damage in school facilities in Southern California. Available at <a href="http://www.scec.org/instanet/00news/images/mcgavin/sld001.htm">http://www.scec.org/instanet/00news/images/mcgavin/sld001.htm</a>
University of California, Berkeley	Non-proprietary Details	UC Berkeley: Q-Brace Quake Bracing Guidelines	2005		Guidelines developed for University of California, Berkeley campus facilities. Includes detailed solutions for contents identifying vendor supplied products or size of hardware to use.
USACERL TR-98/34	Photos, Mitigation	Seismic Mitigation for Equipment at Army Medical Centers	1998		Presents simple methods for reducing the seismic vulnerability of equipment at Army medical centers. Illustrations, observations, and recommendations are based on examples from Madigan Army Medical Center (MAMC). Concerns about particular well-anchored critical medical equipment are presented. Published by the U.S. Army Construction Engineering Research

**Table G-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)**

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
					Laboratories.
VISCMA 101-07	Sample Specification	Seismic Restraint Specification Guidelines  for Mechanical, Electrical And Plumbing Systems	2007		Sample specification for seismic restraint of mechanical, electrical and plumbing equipment. Published by the Vibration Isolation and Seismic Control Manufacturer's Association, Wayne, Pennsylvania.

**Table G-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)**

Product Source/Vendor	Product or Service Description	Comments
Chatsworth Seismic Protection Products	Chatsworth Seismic Protection Products	Variety of seismic protection products. Available at <a href="http://www.twacomm.com/catalog/dept_id_644.htm">http://www.twacomm.com/catalog/dept_id_644.htm</a>
Flexhead	Flexible fire protection	Proprietary flexible connection for sprinklers heads. Available at <a href="http://www.flexhead.com/">http://www.flexhead.com/</a>
Hilti	Concrete anchors and hardware	Information on product selection, different installation systems, and load data. Available at <a href="http://www.hilti.com">www.hilti.com</a>
International Seismic Application Technology	International Seismic Application Technology (ISAT) Applications and Design Manual	Focuses exclusively on mechanical, electrical, plumbing equipment and piping. Includes load tables and details showing use of products. Available at <a href="http://www.isatsb.com">www.isatsb.com</a>
International Seismic Application Technology	2003 IBC Specification - Seismic Restraint of Suspended Utilities	Sample specification available at <a href="http://www.isatsb.com">www.isatsb.com</a>
Kinetics Noise Control	Kinetics noise control seismic restraint capabilities	Brochure presents restraint systems that serve to limit the movement of equipment during a seismic event. Available at <a href="http://www.kineticsnoise.com/hvac/pdf/seismic%20restraint%20capabilities.pdf">http://www.kineticsnoise.com/hvac/pdf/seismic%20restraint%20capabilities.pdf</a>
Loos & Co	Proprietary details approved by	Includes collections of details, such as: Section 7, Sway Brace Components, Installation



**Table G-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)**

Product Source/Vendor	Product or Service Description	Comments
	OSHPD for use in California hospitals	Instructions and Details. Available at <a href="http://www.earthquakebrace.com">www.earthquakebrace.com</a>
Mason Industries	Details, Handbook, and online resources	Available at <a href="http://www.mason-ind.com/html/about.htm">http://www.mason-ind.com/html/about.htm</a> or <a href="http://209.200.80.33/html/seismic_engineering_index.htm">http://209.200.80.33/html/seismic_engineering_index.htm</a>
Metraflex	Thermal and seismic expansion joints for pipe	Available at <a href="http://www.metraflex.com/seismic_met.php">http://www.metraflex.com/seismic_met.php</a>
Pacific Seismic Products	ASCE 25-97 listed seismic actuated valves for residential, commercial and industrial applications	Gas shut off valves and other seismic actuated devices. Available at <a href="http://www.psp4gasoff.com/aboutpsp.htm">http://www.psp4gasoff.com/aboutpsp.htm</a>
Ridg-U-Rak	Isolation system for storage racks	Isolation test of storage racks, both with and without transverse isolation. Movie of test available on website. Available at <a href="http://www.ridgurak.com">http://www.ridgurak.com</a>
Technotes Issue No. 21 RWDI Consulting Engineers and Scientists	Base isolation system for museum pieces or equipment	"Seismic Protection of Museum Artifacts using Base Isolation," Bujar Myslimaj, Ph.D., P.Eng., Senior Specialist, Scott Gamble B.Sc., P.Eng., Principal, Ray Sinclair, Ph.D., Principal. Available at <a href="http://go.rwdi.com/technotes/t21.pdf">http://go.rwdi.com/technotes/t21.pdf</a>
Safety Central	Earthquake safety fasteners, furniture straps, and emergency preparedness	Available at <a href="http://www.safetycentral.com">www.safetycentral.com</a>

**Table G-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)**

Product Source/Vendor	Product or Service Description	Comments
	supplies	
Secure Quick	Secure Quick Seismic Fastening System	Consists of steel cable, wall bracket, and cable fasteners for attaching furniture to wood stud walls. Also provided on website, "Why You Should Not Use Plastic Tabs Devices, Velcro, Hook and Loop, Nylon Straps or Metal Braces." Available at <a href="http://www.quakesecure.com">www.quakesecure.com</a>
Secure-It	PC Security Hardware	Provides products to secure computer equipment. Intended as protection against theft, but security cables and hardware could also be adapted as seismic restraint for other desktop items. Available at <a href="http://www.secure-it.com/shop/index.php/cPath/21">http://www.secure-it.com/shop/index.php/cPath/21</a>
Seismic Restraints NZ	Hardware and systems for contents: collectables, home, office, school, hospital, lab, and technology.	Available at <a href="http://www.seismicrestraints.co.nz">www.seismicrestraints.co.nz</a>
Seismic Solutions	Seismic restraint for ducts, pipes, cable trays, and equipment using cables	Services include structural design, labor and materials for installation. Available at <a href="http://www.seismicsolutionsinc.com/details.html">http://www.seismicsolutionsinc.com/details.html</a>
Simpson Strong-Tie	Provides load rated straps and ties	Includes link for DIY (Do-it-Yourself) projects that illustrate the use of various connectors and adhesives, which could help with some nonstructural installations. Available at

**Table G-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)**

Product Source/Vendor	Product or Service Description	Comments
		<a href="http://www.strongtie.com/products/categories/diy.html">http://www.strongtie.com/products/categories/diy.html</a>
Strand Earthquake Consultants	Engineering and products for nonstructural seismic mitigation	Distributors for GeoSIG, Pacific Seismic Products, Metraflex, and WorkSafe Technologies.
Taylor Devices, Inc.	Viscous dampers for equipment protection	Available at <a href="http://www.taylordevices.com/SeismicDampers.htm">http://www.taylordevices.com/SeismicDampers.htm</a>
The Preparedness Center	Earthquake safety fasteners, furniture straps, and emergency preparedness supplies	Available at <a href="http://www.preparedness.com">www.preparedness.com</a>
USG	"Seismic Ceiling Resource Center"	Includes a series of technical notes and guidelines related to ceilings, ceiling tracks, and shadow moldings. Available at <a href="http://www.usg.com">www.usg.com</a> and <a href="http://www.seismicceilings.com">www.seismicceilings.com</a>
Viking	Flexible connections for sprinkler heads	Available at <a href="http://www.vikingcorp.com/databook/sprinklers/spk_accessories/070605.pdf">http://www.vikingcorp.com/databook/sprinklers/spk_accessories/070605.pdf</a>

**Table G-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)**

Product Source/Vendor	Product or Service Description	Comments
WorkSafe Technologies	System for base-isolation of equipment	IsoBase™ Seismic Isolation Platform, available at <a href="http://www.worksafetech.com/">http://www.worksafetech.com/</a>
WorkSafe Technologies	Large variety of products for seismic protection of nonstructural components in offices, data centers, hospitals, laboratories, and warehouses.	Available at <a href="http://www.worksafetech.com/">http://www.worksafetech.com/</a>

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

<b>Document Number/Source</b>	<b>Title</b>	<b>Author(s)</b>	<b>Publication Date</b>	<b>Comments</b>
8NCEE-002034	Enhancing the Resilience of Acute Care Facilities: An Overview of MCEER Research	Filiatrault, A., et al.	2006	Paper at 8th National Conference on Earthquake Engineering, San Francisco, California.
13WCEE-00295	Overturning Criteria for Non-Anchored Non-Symmetric Rigid Bodies	Boroschek, R.L., and Romo, D.	2004	Theoretical discussion of the effect of non-symmetric bodies subjected to overturning. Paper at 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada.
ATC-29	Proceedings of a Seminar on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures		1992	Includes information on seismic design, performance, and research pertaining to nonstructural components. Funded by the National Center for Earthquake Engineering Research and the National Science Foundation.
ATC-29-1	Proceedings of a Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components		1998	Includes information on seismic design, performance, and research pertaining to nonstructural components. Funded by the National Center for Earthquake Engineering Research and the National Science Foundation.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
ATC-29-2	Proceedings of Seminar on Seismic Design, Performance, and Retrofit of Nonstructural Components in Critical Facilities		2003	Focused principally on nonstructural components and systems in facilities with critical functions. Includes information on the state of the art, state of the practice, and efforts needed to improve both. Prepared in cooperation with the Multidisciplinary Center for Earthquake Engineering Research, and funded by the National Science Foundation.
ATC-38	Database on the Performance of Structures Near Strong-Motion Recordings: 1994 Northridge, California, Earthquake		2001	Effort to correlate structural and nonstructural damage with ground motion parameters recorded during the 1994 Northridge Earthquake. Report includes a CD-ROM with Access database, Excel files, text files, and collection of over 500 photos. Database includes some nonstructural damage data in the following categories: "cladding separation or damage," "partitions damage," "windows damage," "lights and ceilings damage," and "Building Contents Damage." Most photos do not show damage, but provide an overview of the building from street. Report also includes the ATC-38 Postearthquake Building Performance Assessment Form and Surveyor Instructions. Nonstructural categories include Exterior Cladding/Glazing; Partitions; Ceilings; Plumbing, Electrical, Lighting, HVAC; Fire Protection; Major Fixed Equipment, Elevators, Chimneys, and Unusual Contents.
ATC-58	Proceedings: Mini-Workshop/Invited Meeting on the Identification of		2005	ATC-58 Project workshop focusing on the selection of a nonstructural component taxonomy, and identifying nonstructural components that are significant to the estimation of casualty, direct economic, and downtime losses from earthquake damage.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
	Nonstructural Components of Significance			
ATC-58	Guidelines for Seismic Performance Assessment of Buildings, ATC-58 35% Complete Draft		2007	Interim report on methodology for seismic performance assessment of new and existing buildings. Methodology will be applicable to most common building types designed and constructed in the United States within the past 50 years, and will estimate losses in terms of casualties, direct economic losses, and downtime as a result of earthquake damage. Loss estimation is based on fragility curves, which will be provided for both structural and nonstructural components.
FEMA 349	Action Plan for Performance Based Seismic Design		2000	Predecessor document to FEMA 445. Prepared by the Earthquake Engineering Research Institute for FEMA.
FEMA 445	Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings	2006	Section 4.2	Describes how performance-based seismic design guidelines will be developed under the ATC-58 Project. Section 4.2 refers specifically to the development of nonstructural performance products.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
EERI	Learning from Earthquakes: a Survey of Surveys.	Porter, K.	2002	Taken from an EERI Invitational Workshop: An Action Plan to Develop Earthquake Damage and Loss Data Protocols, September 19-20, 2002, Doubletree Hotel, Pasadena, California.
MCEER	ASHRAE Consortium Investigates Performance of Roof-Top Air Handling Unit		Future	MCEER's ASHRAE Consortium is beginning Phase II studies involving shake table testing of a rigidly anchored and vibration isolated roof-top air handling unit. Testing will begin in March 2008 in the Structural Engineering and Earthquake Simulation Laboratory (SEESL) at the University at Buffalo. Studies will focus on developing a specialized numerical model capable of analyzing the seismic response of various types of HVAC equipment mounted on ASHRAE-type isolation/restraint systems.
MCEER	Seismic Vulnerability and Protection of Nonstructural Components	T.T. Soong and D. Lopez Garcia	2003	Addresses seismic vulnerability and protection strategies. Divides nonstructural items into 3 categories: Unrestrained Nonstructural Components; Restrained Nonstructural components; and Nonstructural Systems, which consist of systems of nonstructural components. Cites examples of fragility curves developed for each category. Contains discussion of both damping systems and isolation systems as protection strategies. Ends with recommendations for 6 tasks: (1) Develop a Catalog of Nonstructural Components, Systems and Contents; (2) Identify Nonstructural Performance Measures; (3) Identify Engineering Demand Parameters; (4) Develop Damage Database; (5) Establish Comprehensive Testing and Certification Protocols; and (6) Performance Evaluation Case Studies/Test bed Checks.



**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
MCEER-99-0014	MCEER Nonstructural Damage Database	Kao, A., and Soong, T.T.	1999	Database of earthquake damage to nonstructural elements.
MCEER-05-0005	"Simulation of Strong Ground Motions for Seismic Fragility Evaluation of Nonstructural Components in Hospitals"	Wanitkorkul, A. and Filiatrault, A.	2005	Published by the Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo, State University of New York.
MCEER-06-0001	Seismic Fragility of Suspended Ceiling Systems	Badillo-Almaraz, Whittaker, Reinhorn, Cimellaro	2006	Report on testing of Armstrong ceiling systems. Concludes that compression bars and retention clips help in the behavior of ceilings, and that undersized tiles are a detriment.
PEER 1998/05	Rocking Response and Overturning of Equipment Under Horizontal Pulse-Type Motions	N. Makris, Y. Roussos	1998	Published by the Pacific Earthquake Engineering Research Center, Berkeley, California.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
PEER 1999/06	Rocking Response and Overturning of Anchored Equipment under Seismic Excitations	N. Makris, J. Zhang	1999	Results of shake table testing.
PEER 2001/14	Rocking Response of Equipment Anchored to a Base Foundation	N. Makris, C. Black	2001	Example of PEER research related to Lifelines. PEER has done series of tests funded by PG&E on electrical substation equipment including rigid bus connectors, flexible bus connectors, transformer bushings, and heavy substation equipment.
PEER 2002/01	Nonstructural Loss Estimation: The UC Berkeley Case Study	M. Comerio, J. Stallmeyer	2002	Case studies of loss estimation for five University of California Berkeley campus buildings. Includes a table (Table 10) showing costs assumed for many types of equipment, and photos of lab equipment.
PEER 2002/05	Guidelines, Specifications, and Seismic Performance Characterization of Nonstructural Building Components and Equipment	Filiatrault, A., Christopoulos, C, and Stearns, C.	2001	Contents include chapters on nonstructural earthquake damage. Nonstructural items are divided into 5 groups: contents; building service equipment; building utilization equipment; interior architectural elements; and exterior architectural elements. Overview of various design guidelines and inventory of previous analytical and experimental studies. Includes recommendations, and comprehensive list of references.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
PEER 2003/05	Response Assessment of Nonstructural Building Elements	S. Taghavi, E. Miranda	2003	Proposes a taxonomy (classification) of nonstructural elements by functionality, modes of failure, acceleration-sensitive or drift-sensitive response parameter, and repercussions of damage. Provides damageability, cost, and loss data for 200 elements. Includes a Nonstructural Damage Inventory Form used following the Nisqually Earthquake.
PEER 2003/12	Implementation Manual for the Seismic Protection of Laboratory Contents: Format and Case Studies	W. Holmes, M. Comerio	2003	Presents case studies for University of California Berkeley campus labs. Suggests format for User's Manual that could be used to help occupants install do-it-yourself details for a particular facility.
PEER 2005/03	A Taxonomy of Building Components for Performance-Based Earthquake Engineering	Porter, Keith	2005	Provides a detailed taxonomy (classification) of nonstructural components. Each component is assigned a unique identification number. The list differentiates between anchored and unanchored versions of the same item.
PEER 2005/05	Performance Characterization of Bench- and Shelf-Mounted Equipment	S. Chaudhuri and T. Hutchinson	2005	

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
PEER 2005/07	Experimental and Analytical Studies on the Seismic Response of Freestanding and Anchored Laboratory Equipment	D. Konstantinidis, N. Makris	2005	Shake table testing of equipment.
PEER 2005/12	PEER Test bed Study on a Laboratory Building: Exercising Seismic Performance Assessment	M. Comerio	2005	Test bed performance assessment of the UC Science Building linking performance of contents to operational failure. Shows the interdependence of building structure, systems, and contents in performance assessment, and highlights where further research is needed.
SUNY Buffalo	Nonstructural Components Simulator (NCS).		Future	Specialized equipment for testing nonstructural components. University at Buffalo's NEES (UB-NEES) facility is commissioning a dedicated Nonstructural Component Simulator (NCS). The NCS is a modular and versatile two-level platform for experimental performance evaluation of nonstructural components and equipment under realistic full scale floor motions. NCS can provide the dynamic stroke necessary to replicate full-scale displacements, velocities and accelerations at the upper levels of multi-story buildings during earthquake shaking. Both displacement sensitive and acceleration sensitive nonstructural components and equipment can be experimentally evaluated under full-scale floor motions to understand, quantify and control their seismic response.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

<b>Document Number/Source</b>	<b>Title</b>	<b>Author(s)</b>	<b>Publication Date</b>	<b>Comments</b>
SUNY Buffalo, CSEE-SEESL-2004-02	"Shake Table Testing of Frazier Industrial Storage Pallet Racks"	Filiatrault, A. and Wanitkorkul, A.	2004	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2005-01	"Seismic Qualification By Shake Table Testing of a Centrifugal Liquid Chiller according to AC-156 Testing Protocol"	Filiatrault, A. and Wanitkorkul, A.	2005	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2005-03	"Shake Table Testing of Ridg-U-Rak Rigid Based and Ridg-U-Rak Patent Pending Base Isolated Industrial Storage Racks"	Filiatrault, A., Wanitkorkul, A. and Seo, J-M.	2005	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2005-05	"Seismic Qualification of a Centrifugal Liquid Chiller by Shake Table Testing"	Filiatrault, A. and Wanitkorkul, A.	2005	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2006-	"Experimental Seismic Performance Evaluation of ASRAE-Type	Fathali, S. and Filiatrault, A.	2006	Published by the University at Buffalo, State University of New York, Buffalo, New York.

**Table G-5 Recent and Ongoing Research Related to Nonstructural Components (continued)**

Document Number/Source	Title	Author(s)	Publication Date	Comments
05	Isolation/Restraint Systems”			
SUNY Buffalo, CSEE-SEESL-2006-07	“Shake Table Testing of Ridg-U-Rak Rigid Based and Ridg-U-Rak Patent Pending Base Isolated Industrial Storage Racks: Production Unit Testing”	Filiatrault, A., and Wanitkorkul, A.	2006	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2006-19	“Shake Table Testing of Ridg-U-Rak Rigid Based and Ridg-U-Rak Patent Pending Base Isolated Industrial Storage Racks: Final Production Unit Testing”	Filiatrault, A., and Wanitkorkul, A.	2006	Published by the University at Buffalo, State University of New York, Buffalo, New York.
University of Chile	Controlled Overturning of Unanchored Rigid Bodies	Boroschek, R.L., and Iruretagoyena, A.		Review of test results for equipment on an inclined surface. Results show that an incline can force overturning to occur in a preferred direction. For example, a 3-degree angle will result in an 89% probability that blocks will overturn in that direction. Could be useful information for keeping contents on shelves.