# 5
# Concluding Remarks

There are many reasons for considering a seismic qualification program for facilities located in earthquake prone areas. These programs are required by code for essential facilities and can be equally justified by environmental and economical reasons for most other types of facilities. Building equipment is sometimes reduced to a useless pile of rubble by an earthquake even when the building structure itself is left intact. The comprehensive seismic qualification program suggested in this book is geared to reduce the potential for damage to all building equipment whether it is for a hospital, library, refinery, school, or other building. Most facilities can benefit by some measure of protection if they are located in an earthquake prone area

The review of building codes in Appendix 1 shows that most of them typically approach the equipment qualification problem from a static point of view. While it is a valid method of qualification for many types of equipment, it is just as invalid for other types. This book presents the reader with the basics for qualification programs that utilize methods that are specifically suited to the requirements and characteristics of each individual piece of equipment. Earthquake testing is required for critical equipment that is likely to fail operationally rather than structurally. Dynamic analyses are required for equipment that is likely to wiggle extensively because of its geometry and is not likely to fail operationally The static analysis is valid for the type of equipment that is generally rigid and only needs to remain anchored to be operational and not collide with other more critical equipment

This book introduces the reader to a method whereby all equipment can be assigned to a seismic category, which then lends itself to examination and qualification by one of the two model seismic design specifications presented. All this information is provided for various types of equipment and is referenced to idealized diagrammatic installation details in Chapter 4 and Appendix 3. The qualification methods presented herein are intended for use by all those interested in the survivability of building equipment during and after an earthquake.

Research programs are currently needed to refine the coefficients used by codes in the static formulas. Seismic testing programs can be designed for and conducted on typical equipment installations that will yield coefficients that are more valid than those currently employed The National Science

Foundation and some university and private testing laboratories are currently pioneering in these efforts. Upgraded codes from these findings recognize the dynamic nature, as well as the operability requirements, of equipment that will certainly result in facilities less likely to be damaged as a result of an earthquake. Examples of such endeavors include research on the nonstructural behavior of the county services building (during the 1979 Imperial Valley Earthquake) by Chris Arnold at Building Systems Development in Palo Alto and Dr. Satwant Rihal's research on the seismic performance of nonstructural partition walls at Cal-Poly San Luis Obispo. Extensive testing programs are continuously being conducted at private companies such as Wyle Laboratories seismic simulators at Norco, California and Huntsville, Alabama, and at ANCO in Santa Monica, California.

The approaches that are presented to the reader are not new and have been utilized by critical facilities such as nuclear power plants for more than a decade. The technology exists to attain a relatively high level of confidence with respect to survivability of equipment after a severe earthquake and is only waiting to be employed.

# Bibliography


Anderson Thomas L., and Douglas J Nyman. "Lifeline Earthquake Engineering for Trans Alaska Pipeline System," *The Current State of Knowledge of Lifeline Earthquake Engineering*. American Society of Civil Engineers, U C.L.A , 1977

Ayres, J Marx, T Y Sun, and F. R. Brown. *Report on Nonstructural Damage to Buildings Due to the March 27 1964 Alaska Earthquake* National Academy of Sciences, Committee on the Alaskan Earthquake Engineering Panel, 1967

Ayres, J. Marx and Tseng-Yao Sun "Nonstructural Damage." *San Fernando, California Earthquake of February 9. 1971.* L. M Murphy, Ed. Volume 1, Part B N O A A., Washington, D.C , 1973

Ayres, J. Marx, and Tseng-Yao Sun "Criteria for Building Services and Furnishings," *Building Practices for Disaster Mitigation.* Richard Wright, Samuel Kramer, and Charles Culver, Eds., National Bureau of Standards, Science Series 46, U. S. Department of Commerce, Workshop, 1972, issued February 1973.

*Basis for Seismic Restraint Design of Mechanical and Electrical Service Systems* G M and T. R Simonson Company and E.D.A.C A National Science Foundation report, May 1976

Benkert, Donald, *Earthquake Protection of Vibration Isolated Equipment*, California Dynamics Corporation Sales Brochure, File 62, 1976.

Benuska, K. L., S. Aroni, and W. Schroll. "Elevator Earthquake Safety Control," *6th World Conference on Earthquake Engineering*. New Delhi, India, 1977.

Earthquake Damage to General Telephone Company of California Facilities " General Telephone Company of California, Santa Monica, California. *San Fernando, California Earthquake of February 9, 1971.* L. M Murphy, Ed. Volume 1, Part B, N.O A.A , Washington, D.C., 1973

"Earthquake Damage to Pacific Telephone and Telegraph Company Facilities." Pacific Telephone and Telegraph Company. *San Fernando, California Earthquake of February 9, 1971* L M Murphy, Ed. Volume 1, Part B N O.A A , Washington, D C , 1973

"Earthquake Damage to Southern California Edison Company Power Facilities " Southern California Edison Company *San Fernando, California Earthquake of February 9, 1971* L. M. Murphy, Ed. Volume 1, Part B N O.A A , Washington, D C , 1973

*Earthquake Resistant Regulations A World List 1973* Compiled by the International Association for Earthquake Engineering Published by Gakujutsu Bunken Fukyu-Kai, Japan, April 1973.

*Earthquake Resistant Regulations A World List 1973 Supplement 1976.* Compiled by the International Association for Earthquake Engineering. Published by Gakujutsu Bunken Fukyu-Kai, Japan, 1976.

Eckel, E. B "The Alaskan Earthquake: March 27, 1964, Lessons and Conclusions," *U S G S. Prof. Paper 546* 1970.

Housner, George W. "Strong Ground Motion." *Earthquake Engineering*. Robert L. Wiegel, Ed., Prentice-Hall, Inc., Englewood Cliffs, N.J., 1970, Chapter 4.

IEEE Standard 344—1975, *IEEE Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations*, New York, 1975.

Iacopi, Robert. *Earthquake Country*. A Sunset Book, Lane Magazine and Book Company, Menlo Park, California, 1971.

Ibanez, Paul, and W. E. Gundy. "Plant Engineering in Earthquake Country," *Proceedings of the Western Plant Engineering Conference and Show*. Anaheim, California, 1977.

Iwan, W. D. "Predicting the Earthquake Response of Resiliently Mounted Equipment with Motion Limiting Constraints," *6th World Conference on Earthquake Engineering*, New Delhi, India, 1977.

Jordan, Carl H. "Seismic Restraint of Equipment in Buildings," *Proceedings of the A.S.C.E. Annual Convention*, Volume 104, Number ST 5, 1978.

Kemper, Alfred M. *Architectural Handbook*. John Wiley & Sons, New York, 1979.

Leeds, David J. "The Design Earthquake," *Geology, Seismicity, and Environmental Impact*. Association of Engineering Geologists Special Publication. D. M. Moran, J. E. Slosson, R. O. Stone, and C. A. Yelverton, Eds. University Publishers, Los Angeles, California, October 1973.

Legget, Robert F. *Cities and Geology*. McGraw-Hill Book Company, New York, 1973.

Liu, S. C. "Earthquake Protection of Communication Facilities," *6th World Conference on Earthquake Engineering*, New Delhi, India, 1977.

*Long Beach Municipal Building Code*, California, 1973.

*Los Angeles Building Code*. California, 1975.

Mason, Norman J., and Patrick J. Lama. *Seismic Control Specifications for Floor Mounted Equipment*. Mason Industries, Inc. Sales Brochure SCS-100 Bulletin, Los Angeles, California, no date.

McCue, Gerald M., Ann Skaff, and John W. Boyce. *Architectural Design of Building Components for Earthquakes*. Sponsored by the National Science Foundation, Research Applied to National Needs Program, Washington, D.C., 1978.

McGavin, Gary L. *Seismic Qualification of Nonstructural Equipment in Essential Facilities*, unpublished Master of Architecture thesis, California State Polytechnic University, Pomona, 1978.

McGavin, Gary L. "An Examination of Aseismic Legislation for Nonstructural Components in Essential Facilities," *Proceedings of the 2nd U.S. National Conference on Earthquake Engineering*. Earthquake Engineering Research Institute, Stanford, California, 1979.

Merz, K. L. "Seismic Design & Qualification Procedures for Equipment Components of Lifeline Systems." *The Current State of Knowledge of Lifeline Earthquake Engineering*, Proceedings of the Technical Council on Lifeline Earthquake Engineering, A.S.C.E., U.C.L.A., 1977.

Miller, Richard K., and Stephen F. Felszeghy. *Engineering Features of the Santa Barbara Earthquake of August 13, 1978*, University of California Santa Barbara-ME-78-2 and Earthquake Engineering Research Institute, December 1978.

Muto, Kiyoshi, Masayuki Nagata, and Eiji Fukuzawa. "Earthquake Resistant Installation Device of Computers." *6th World Conference on Earthquake Engineering*, New Delhi, India, 1977.

Newmark, Nathan M., and E. Rosenblueth. *Fundamentals of Earthquake Engineering*. Prentice-Hall, Inc. Englewood Cliffs, N.J., 1971.

*Recommended Lateral Force Requirements and Commentary*. Seismology Committee Structural Engineers Association of California, San Francisco, 1975.



Reitherman, Robert K. "Some Notes on Nonstructural Features of the August 6, 1979 Coyote Lake Earthquake," *Earthquake Engineering Research Institute Newsletter*, November 1979.

Richter, Charles F. *Elementary Seismology*. W. H. Freeman and Company, San Francisco, 1958.

Roberts, Charles W. "Environmental Simulation—A Powerful Tool for the Product Designer," unpublished Wyle Laboratories paper, El Segundo, California, 1977.

*Rule of General Application. Recommended Standards for Suspended Ceiling Assemblies*, Los Angeles, California, 1974.

*Seismic Design for Buildings*. (Draft) Technical Manual No. 5-809-10, Departments of The Army, Air Force and Navy, August 1979.

*Seismic Safety Design for Police and Fire Stations*. A.I.A. Research Corp. and Public Technology, Inc., Washington D.C., 1977.

Shipway, George. "Seismic Seminar," unpublished Wyle Laboratories seminar text, El Segundo, California, 1974.

*Specification 9618, Part F, Division F1, Section F1A, Article 27*, City of Los Angeles Department of Water and Power, issued in connection with Energy Control Project, no date.

*State of California, California Administrative Code*, Title 24, Building Standards; Part 3, Basic Electrical Regulations, Sacramento, California, 1974.

*State of California, California Administrative Code*, Title 24 Building Standards, Part 4, Basic Mechanical Regulations, Sacramento, California, 1971.

*State of California, California Administrative Code*, Title 24 Building Standards, Part 5, Basic Plumbing Regulations, Sacramento, California, 1971.

*State of California, California Administrative Code*, Title 24 Building Standards, Part 6, Special Building Regulations, Division T17, State Department of Public Health, Sacramento, California, 1974.

*State of California, California Administrative Code*, Title 24 Building Standards, Part 7, Elevator Safety Regulations, Sacramento, California, 1977.

Steinbrugge, K. V., and H. J. Degenkolb. "Meeting the Earthquake Challenge: California's New Laws." *Civil Engineering*. American Society of Civil Engineers, February 1975.

Stone, Marraccini, and Patterson. *Study to Establish Seismic Protection Provisions for Furniture, Equipment and Supplies for VA Hospitals*, Research Staff Office of Construction, Veterans Administration, Washington, D.C., 1976.

Sugimoto, Yoneo, and Yuji Sato. "Telecommunications Equipment Seismic Effect Study," *6th World Conference on Earthquake Engineering*, New Delhi, India, 1977.

*Summary of Veterans Administration Earthquake Engineering Program*. Veterans Administration, Washington, D.C., March 1977.

*Summer Seismic Institute for Architectural Faculty*. A.I.A. Research Corporation. Sponsored by the National Science Foundation, Research Applied to National Needs Program, Stanford University, 1977.

*Tentative Provisions for the Development of Seismic Regulations for Buildings*, prepared by Applied Technology Council, ATC 3-06, National Bureau of Standards, NBS 510, National Science Foundation, NSF 78-8, Washington, D.C., 1978.

*Uniform Building Code*. International Conference of Building Officials, Whittier, California, 1979.

*Urban Geology Master Plan for California*. California Division of Mines and Geology, Bulletin 198, 1973.

*VA Construction Standard CD-54, H-08-3*. Veterans Administration, Washington, D.C., August 1975.

*VA Construction Standard CD-55, H-08-3*. Veterans Administration, Washington, D.C., November 1973.

Wong, Patrick P. "Earthquake Effects on Power System Facilities of the City of Los Angeles." *San Fernando California Earthquake of February 9, 1971* L. M. Murphy, Ed. Volume 1, Part B. N.O.A.A., Washington, D.C., 1973.

Yancey, C. W. C., and A. A. Camacho. Aseismic Design of Building Service Systems. The State-of-the-Art, National Bureau of Standards Technical Note 970, Washington, D.C., 1978.

Yanev, Peter I. *Peace of Mind in Earthquake Country*. Chronicle Books, San Francisco, California, 1974.

Yuceoglu, U. *Seismic Design of Equipment Supports and Connections in Industrial Installations—A Brief Summary*. ASME paper 80-C2/PVP-73, New York, N.Y., 1980.