SEAOC Blue Book: Seismic Design Recommendations 1959 to 2008

J. Diebold[1], K. Moore[2], T. Hale[3], and G. Mochizuki[4]

[1] *Past Chair, SEAOC Seismology Committee, Sacramento, California, USA*
[2] *Chair, SEAOC Seismology Committee, San Francisco, California, USA*
[3] *SEAOCC Chair, SEAOC Seismology Committee, Sacramento, California, USA*
[4] *Chair, Light Frame Subcommittee, SEAOC Seismology Committee, San Francisco, California, USA*

Email: jdiebold0505@bellsouth.net, moore@certuscorp.net

ABSTRACT :

Following the publication of the 1927 Uniform Building Code (UBC), California structural engineers, working as volunteers through the Structural Engineers Association of California (SEAOC) Seismology Committee, led international efforts to develop seismic provisions for building codes. As this effort grew, SEAOC began work on publishing specific building code provisions, as a statewide effort. SEAOC first published the Recommended Lateral Force Requirements, also known as the Blue Book, in 1959. The first commentary on seismic design practice was published in 1960. Thus began SEAOC's role in the development of seismic provisions for incorporation into building code regulations, as well as its role in providing a commentary on existing building code seismic provisions to assist design engineers. The SEAOC Seismology Committee reviews university research, U.S. Geological Survey technical publications, and work completed by individual practicing engineers to develop practical design detailing provisions and building code regulation enhancements. Following the occurrence of major earthquakes between 1970 and 1994, SEAOC worked on enhancements to seismic design that addressed the lessons learned from these earthquakes. The Blue Book and the UBC seismic provisions have been recognized throughout the world as leading references for the design of earthquake resistant buildings. As a forum for practicing engineers, the Blue Book formalized Seismology Committee positions and interpretations and was widely viewed as a preliminary version of future seismic code provisions and a commentary on the UBC. From its seminal publication in 1959 through its internet presence in 2008, the Blue Book has held a commanding position in furthering the understanding of structural seismic design.

KEYWORDS: Recommended Lateral Force Requirements, SEAOC, Blue Book, California, Seismology Committee, ATC, BSSC, NEHRP

1. EARLY DAYS…

The Structural Engineers of California (SEAOC) developed the *Recommended Lateral Force Requirements*, also known as the Blue Book, in response to the needs of its members, the people of the State of California, and others that seek guidance with regard to seismic design. For California engineers, the story begins with the events following the 1906 San Francisco Earthquake through the 1940 El Centro Earthquake. California Structural Engineers played a major role throughout much of this period.

In 1906, seismic design recommendations were intended for buildings taller than 100 feet (or taller than 3 times the building's least dimension) and consisted of applying a 30 psf wind load to the building elevation, ensuring adequate structural strength to resist such an external force, regardless of its expected occurence. As time went on, the recommended wind load was reduced to 20 psf and later 15psf. At that time, however, no building code provisions existed for the design of shorter structures to resist wind or earthquake loads. Some engineers expressed concern over the reduction of the design earthquake wind load from 30 psf to 15 psf. Several structural engineers learned about the seismic behavior of structures by observing building damage caused by earthquakes. This practice of learning from observing damage from the earthquake continues through today, as each earthquake tends to provide some level of education.

The Japan 1923 earthquake and the Santa Barbara 1925 earthquake provided opportunities to observe differences in building performance, observe different levels of building damage and consider possible changes to force levels and detailing provisions to improve building seismic behavior.. Based on observations made during these events, some engineers considered developing earthquake forces as a percentage of the building dead load applied as a lateral load. This method first appeared in the 1927 Uniform Building Code. In addition to promulgating lateral force levels, seismic design regulations asserted that design lateral forces be applied in two orthogonal directions, and distributed to all floor levels in a proportional fashion. Furthermore, the structure was to be interconnected to behave as a system. Around the same time, strong motion earthquake records were being published and studied, resulting in the application of seismic motion instrumentation to several buildings.

After the Santa Barbara earthquake, many California building owners demanded earthquake insurance. Insurance underwriters recently observed heavy damage from the Japan and Santa Barbara earthquakes, which led to an increase in earthquake insurance premiums. In response to increasing earthquake insurance premiums, concerns over poor construction practices, and a sudden recession in building construction, the State Chamber of Commerce Code Committee was formed. The State Chamber of Commerce Code Committee sponsored work by several leading structural engineers culminating in a report published in 1938.

The Long Beach 1933 earthquake triggered mandatory seismic regulations promulgated in two California State laws: the Field Act and the Riley Act. The Field Act established the Division of State Architect to address the seismic concerns for public schools. The provisions of Appendix A of the Field Act were essentially the earthquake provisions put forth by the State Chamber of Commerce. The Riley Act required minimum seismic design requirements for all buildings. These set the direction for future seismic design provisions developed in the future.

Strong motion accelerograph data was recorded during the 1940 El Centro earthquake. This data enabled the comparison and development of response spectra or response histories for dynamic design and analysis. The El Centro ground motion data would serve as a basis for seismic force levels used in future codes for many years.

Through the mid 1940s, the percentage of the dead load used for seismic design varied between 2% and 8%. The percentage of dead load was related to the reciprocal of the number of stories. However, each jurisdiction was following its own local variation of this rule, so there was some inconsistency throughout the state of California. In addition to the changes being made in the Uniform Building Code, a Joint Committee on Lateral Forces of the San Francisco Section of the American Society of Civil Engineers (ASCE) and the Structural Engineers of Northern California (SEAONC) issued a report in 1951 that recommended that the seismic design force coefficients be related to the estimated, or calculated, fundamental period of the structure.

2. BLUE BOOK DEVELOPMENT

Following the publication of the 1927 Uniform Building Code (UBC), California structural engineers, working as volunteers through the Structural Engineers Association of California (SEAOC) Seismology Committee, led international efforts to develop seismic provisions for building codes. These efforts were formalized in the 1940s with separate actions in northern and southern California. As these efforts grew, SEAOC began work on publishing the seismic design provisions, as a statewide California effort. In 1957, SEAOC was tasked with developing a uniform seismic code that could be acceptable to engineers throughout the State of California. The SEAOC Board assigned this task to the newly appointed Seismology Committee. The Seismology Committee reviewed recommendations and detailed studies and after two years issued a report to the SEAOC Board.

2.1. Recommended Lateral Force Requirements, 1959-1960

SEAOC first published the Recommended Lateral Force Requirements, also known as the Blue Book, in 1959. The first commentary on seismic design practice was published in 1960. Thus began SEAOC's role in the development of seismic provisions for incorporation into building codes, as well as its role in providing a commentary on existing building code seismic provisions to assist design engineers. Some of the recommendations are discussed below.

The basic formula for base shear, V_w was developed in 1959 to read:

$$V_w = (ZKC)W$$

Z is the Zone Factor, for which one zone was recommended for the entire state of California
K is a systems factor to account for the type or arrangement of lateral force resisting elements.
C is a function of the cube root of the fundamental period T
W is the weight of the structure

- A method for distributing the base shear, and a formula for the overturning moment was presented in this early set of seismic design provisions.
- The fundamental period T could be based on a prescriptive formula or by other methods based on technical data.
- A requirement for a steel moment frame to resist a minimum of 25% of the seismic forces was required for any building that exceeded 13 stories or 160 ft.

The Blue Book commentary also clarified that recommendations were limited to the provision of life safety – minimum standards to assure public safety.

The Earthquake Engineering Research Institute, EERI, has documented some of this history through the Oral History Series. This series of published interviews provide context to the development of seismic design regulations. The interviewees included: Clarkson W. Pinkham, Henry Degenkolb, Henry J. Brunnier, Karl

Steinbrugge, and Charles De Maria. Other sources of Blue Book history include papers and articles by Structural Engineers who have written regarding the development of building codes and about the SEAOC Blue Book. Some of these are represented in the reference list at the end of this article.

By 1962, the goal of providing a uniform code for seismic design in California was achieved;
the 1960 SEAOC Code was adopted by Los Angeles, San Francisco, and the 1961 Uniform Building Code.

2.2. Blue Book Development and Recommended Lateral Force Requirements, 1967 to 1999

Blue Book development is through the SEAOC Seismology Committee. The SEAOC Seismology Committee reviews university research, U.S. Geological Survey technical publications, and work completed by individual practicing engineers to develop practical design detailing provisions and building code regulation enhancements.

SEAOC Seismology Committee meetings are open to the public and are frequently attended by observers from other structural engineer associations, code officials, construction industry and trade organization representatives, academics and researchers, and individual SEAOC members. Ideas for code enhancements frequently come up through one of the four local chapters and can be assigned to a subcommittee for further development before coming to the committee for discussion and deliberation. It is a longstanding practice of the committee to propose only those code enhancements that have the consensus support of the statewide committee.

Considering the amount of access that the Seismology Committee had to the code change process, the formal process and organization of the Committee is relatively straightforward and is comprised of voting delegates from SEAOC's four local associations:

SEAONC – Northern California (3 delegates), SEAOCC – Central California (2 delegates),
SEAOSC – Southern California (3 delegates), and SEAOSD – San Diego (2 delegates)

When the first Blue Book was completed, it was recognized that earthquake resistant design is constantly changing via new ideas, methods, and research. The SEAOC Seismology Committee continued to review the Blue Book with the intent of improving the recommendations. Because the seismic detailing provisions of the early Uniform Building Code were minimal, the SEAOC Seismology Committee added detailing provisions. For the 1967 UBC, the Seismology Committee introduced ductile detailing requirements for reinforced concrete frames. This was based on pioneering work by John Blume (Blume et al., 1961). The major enhancements in the 1967 Blue Book included:

- Requirements for concrete shear walls, braced frames, and reinforced concrete moment frames.
- Rules for use of concrete moment frames to qualify for the ductility required for buildings over 160 ft in height.
- Special requirements for inspection and design.

The 1971 San Fernando Earthquake convinced leading engineers that the UBC provisions were due for a substantial updating, and that such a task would need to be done outside of the code cycle. SEAOC then created the Applied Technology Council as an independent non-profit organization to seek funding for and to carry out structural engineering research aimed at improving design practice and codes. ATC 3-06 was published in 1978 and became part of the 1988 UBC and 1988 Blue Book. Later, the Building Seismic Safety Council modified ATC 3-06 as needed for incorporation into national model building codes such as the National Earthquake Hazard Reduction Program (NEHRP).

Table 2.1 summarizes some of the Blue Book recommendations that were adopted into the UBC seismic design provisions from 1970 through 1994 (SEAOC Seismology Committee 2005).

Table 2.1. Earthquakes, UBC edition and SEAOC recommended enhancement to UBC

Earthquake	UBC Edition	SEAOC Recommended Enhancement
1971 San Fernando	1973	Direct positive anchorage of masonry and concrete walls to diaphragms
	1976	Seismic Zone 4, with increased base shear requirements
		Base shear dependence on site conditions through coefficient *S*
		Occupancy Importance Factor *I* for certain buildings
		Interconnection of individual column foundations
		Special Inspection requirements
1979 Imperial Valley	1985	Diaphragm continuity ties
1985 Mexico City	1988	Requirements for columns supporting discontinuous walls
		Separation of buildings to avoid pounding
		Design of steel columns for maximum axial forces
		Restrictions for irregular structures
		Ductile detailing of perimeter frames
1987 Whittier Narrows	1991	Revisions to site coefficients
		Revision to spectral shape
		Increased wall anchorage forces for flexible diaphragm buildings
1989 Loma Prieta	1991	Increased restrictions on chevron-braced frames
		Limitations on *b/t* ratios for braced frames
	1994	Ductile detailing of piles
1994 Northridge	1997	Restrictions on use of battered piles
		Requirements to consider liquefaction
		Near-fault zones and corresponding base shear requirements
		Revised base shear equations using 1/*T* spectral shape
		Redundancy requirements
		Design of collectors for overstrength
		Increase in wall anchorage requirements
		More realistic evaluation of design drift
		Steel moment connection verification by test

The Blue Book and the UBC seismic provisions have been recognized throughout the world as leading references for the design of earthquake resistant buildings. In the United States, seismic design requirements in the ANSI A58.1 Standard (National Bureau of Standards, 1982), and in codes published by Building Officials and Code Administrators (BOCA) and Southern Building Code Congress International (SBCCI) were based on Blue Book recommendations.

As an active participant in the UBC development process, SEAOC provided code change proposals, especially those regarding earthquake design provisions. These code changes were usually accepted by the International Conference of Building Officials (ICBO), the code writing body responsible for publishing the UBC. For the 1988 and 1997 code cycles, ICBO accepted SEAOC proposals that were complete rewrites of existing code chapters. Even though SEAOC was not the only organization contributing to the UBC seismic provisions, it did have a dominant influence.

2.3. Seismic Design Recommendations, 2000 through 2008

SEAOC has been aware that the Blue Book has been perceived by some that it is a West Coast document, not suitable for national adoption. Increased focus on interstate and nationwide seismic design triggered the development of a unified set of building code provisions that would be applicable in any jurisdiction in the nation. The establishment of the Applied Technology Council (ATC) and the Building Seismic Safety Council (BSSC) led to the formation of the National Earthquake Hazard Reduction Program (NEHRP) to formalize the process of developing the seismic model building codes. SEAOC continues to participate in this process. The result of these efforts is articulated in the International Building Code, NFPA 5000 and ASCE 7.

This significant change in the code development process indicated that SEAOC would no longer have privileged direct access to the code change process that it had with the UBC. Nevertheless, SEAOC has maintained their involvement in the code development and participates through membership representation on various consensus groups. As a result of the changed code environment, the SEAOC Seismology determined that a technical editor was needed to plan, edit and oversee the development of a new type of Blue Book. Because commentary of code provisions can be found in many different publications, the “new” Blue Book was proposed as a compilation of articles developed by volunteer writers selected from the SEAOC roster with specific expertise.

As a result of this new format, the Blue Book is no longer the source document for any code or standard. Instead the Blue Book is now a source of Seismology Committee positions and recommendations for code changes.

The Seismology Committee decided to provide the articles on-line for faster development, better access and faster distribution in a widely accessible environment. Seismology Committee delegates are responsible for leading the production and review of each article, while the Technical Editor is responsible for final editing and compilation of the articles. Committee members are also responsible for developing code change proposals and review of proposed code changes by other organizations and material standards bodies. Topics covered by the “new” Blue Book include: System Factors, Foundation Modeling, Cantilever Columns, Period Determination, Dual Systems, Concentric Braced Frames, Tilt Up, Special Truss Moment Frame, Seismic Force Resisting Systems, etc.

On April 17, 2006, the Applied Technology Council (ATC) recognized the Recommended Lateral Force Requirements and Commentary (Blue Book Series) as a Top Seismic Product of the 20th Century.

The Blue Book formalized Seismology Committee positions and interpretations and was widely viewed as a preliminary version of the coming seismic code and a commentary on the UBC. The Blue Book, in its new form as an online clearinghouse of seismic engineering ideology, will continue to serve as a basis for seismic code development and future direction for seismic engineering practice. From its debut publication in 1959 through its internet presence in 2008, the Seismic Design Recommendations (aka Blue Book) play an important part in furthering the understanding of structural seismic design.

REFERENCE

ATC (1978). Tentative Provisions for the Development of Seismic Regulations for Buildings (ATC 3-06), Applied Technology Council, Redwood City, CA. (A second printing, in 1984, includes 1982 amendments.)

Bachman, R. E. (1995). "Briefing on the 1995 Blue Book, approved seismic code provisions for the 1996 UBC Supplement and proposed 1997 UBC seismic provisions for strength design," Proceedings: 64th Annual Convention, Structural Engineers Association of California.

Blume, J. A., Newmark, N. M., and Corning, L. H. (1961). Design of Multi-story Concrete Buildings for Earthquake Motions, Portland Cement Association.

BSSC (2001a). NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, 2000 Edition, Part 1—Provisions (FEMA 368). Building Seismic Safety Council, Washington, D.C., March.

BSSC (2001b). NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, 2000 Edition, Part 2—Commentary (FEMA 369). Building Seismic Safety Council, Washington, D.C., March.

Degenkolb, H. J. (1986). "Code provisions resulting from earthquake observations," in Learning from Earthquakes, Structural Engineers Association of Northern California, San Francisco, March.

EERI (1994). Clarkson W. Pinkham (OHS-1), in Connections: The EERI Oral History Series, Earthquake Engineering Research Institute, Oakland.

EERI (1994). Henry J. Degenkolb (OHS-1), in Connections: The EERI Oral History Series, Earthquake Engineering Research Institute, Oakland.

Holmes, W. T. (1998). "The history of U.S. seismic code development," Past, Present and Future Issues in Earthquake Engineering: The E.E.R.I. Golden Anniversary Vol, 1948-1998, Earthquake Engineering Research Institute, p. 13-18.

McClure, Frank E. (2006) Modern Earthquake Codes: History and Development, Reprint: Computers and Structures Inc.

Olson, R. A. (2003). "Legislative politics and seismic safety: California's early years and the 'Field Act,' 1925-1933," Earthquake Spectra, v.19 n.1, February.

OSHPD (2003). Evaluation of the 2003 Model Codes: Final Report, Office of Statewide Health Planning and Development, July 29. Available at www.oshpd.state.ca.us/fdd/About_Us/Organization/Regulations/EVALfinal-ALL.pdf.

PCBO (1928). Uniform Building Code, Whittier, CA.

Porush, A. R. and Zacher, E. G. (1987). "SEAOC, the Blue Book and seismic codes: past, present, and future," Proceedings: 56th Annual Convention, Structural Engineers Association of California.

SEAOC Seismology Committee (2005) "Development of Earthquake Design Provisions for Building Codes", September, 2005, The SEAOC Blue Book: Seismic Design Recommendations, Structural Engineers Association of California, Sacramento, CA. Accessible via the world wide web at: http://www.seaoc.org/bluebook

SEAOC Seismology Committee (2005) "Preface to the Online Edition", September, 2005, The SEAOC Blue Book: Seismic Design Recommendations, Structural Engineers Association of California, Sacramento, CA. Accessible via the world wide web at: http://www.seaoc.org/bluebook

SEAOC Seismology Committee (2007) "Development of System Factors", January, 2007, The SEAOC Blue Book: Seismic Design Recommendations, Structural Engineers Association of California, Sacramento, CA. Accessible via the world wide web at: http://www.seaoc.org/bluebook

Seismology (1959). Recommended Lateral Force Requirements, Seismology Committee, Structural Engineers Association of California, July.

Seismology (1960). Recommended Lateral Force Requirements and Commentary, Seismology Committee, Structural Engineers Association of California.

Seismology (1999). Recommended Lateral Force Requirements and Commentary, Seismology Committee, Structural Engineers Association of California.