Appendix to Chapter 14

OTHER NONBUILDING STRUCTURES

PREFACE: The following sections were originally intended to be part of the Nonbuilding Structures Chapter of this Commentary. The *Provisions* Update Committee felt that given the complexity of the issues, the varied nature of the resource documents, and the lack of supporting consensus resource documents, time did not allow a sufficient review of the proposed sections required for inclusion into the main body of the chapter.

The Nonbuilding Structures Technical Subcommittee, however, expressed that what is presented herein represents the current industry accepted design practice within the engineering community that specializes in these types of nonbuilding structures.

The *Commentary* sections are included here so that the design community specializing in these nonbuilding structures can have the opportunity to gain a familiarity with the concepts, update their standards, and send comments on this appendix to the BSSC.

It is hoped that the various consensus design standards will be updated to include the design and construction methodology presented in this Appendix. It is also hoped that industry standards that are currently not consensus documents will endeavor to move their standards through the consensus process facilitating building code inclusion.

A14.1 GENERAL

Agrawal P. K., and J. M. Kramer, Analysis of Transmission Structures and Substation Structures and Equipment for Seismic Loading, Sargent & Lundy Transmission and Substation Conference, December 2, 1976. (Agrawal)

American Society of Civil Engineers (ASCE):

ANSI/ASCE 10, *Design of Latticed Transmission Structures*, 1997. (ASCE 10)

ASCE Manual 72, *Tubular Pole Design Standard*, 1991 (ASCE 72).

ASCE Manual 74, *Guidelines for Electrical Transmission Line Structural Loading*, 2000. (ASCE 74).

ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, 1995. (ASCE 7).

ASCE Manual 91, *The Design of Guyed Electrical Transmission Structur*es, 1997. (ASCE 91)

Substation Structure Design Guide, 2000. (ASCE Substation)

Li, H.-N., S. Wang, M. Lu, and Q. Wang, "Aseismic Calculations for Transmission Towers," *ASCE Technical Council on Lifeline Earthquake Engineering*, *Monograph No. 4*, August 1991. (ASCE Li)

Steinhardt, O. W., "Low Cost Seismic Strengthening of Power Systems," *Journal of The Technical Councils of ASCE*, April 1981. (ASCE Steinhardt)

Amiri, G. G. and G. G. McClure, "Seismic Response to Tall Guyed Telecommunication Towers," Paper No. 1982, Eleventh World Conference on Earthquake Engineering, Elsevier Science Ltd., 1996. (Amiri)

Australian Standards:

Australian Standard 3995, *Standard Design of Steel Lattice Towers and Masts*, 1994. (AS 3995)

Canadian Standards Association (CSA):

Antennas, Towers, and Masts, 1994. (CSA S37)

Earthquake Engineering Research Institute (EERI):

Li, H.-N., L. E. Suarez, and M. P. Singh, "Seismic Effects on High-Voltage Transmission Tower and Cable Systems," Fifth U.S. National Conference on Earthquake Engineering, 1994. (EERI Li)

Federal Emergency Management Agency (FEMA):

Earthquake Resistant Construction of Electric Transmission and Telecommunication Facilities Serving the Federal Government, FEMA Report No. 202, September 1990. (FEMA 202)

Galvez, C. A., and G. G. McClure, "A Simplified Method for Aseismic Design of Self-Supporting Latticed Telecommunication Towers," Seventh Canadian Conference on Earthquake Engineering, Montreal, 1995. (Galvez)

Institute of Electrical and Electronics Engineers (IEEE):

National Electrical Safety Code, ANSI C2, New Jersey, 1997. (NESC)

IEEE Standard 693, *Recommended Practices for Seismic Design of Substations*, Power Engineering Society, Piscataway, New Jersey, 1997 (IEEE 693).

IEEE Standard 751, *Trial-Use Design Guide for Wood Transmission Structures*, Power Engineering Society, Piscataway, New Jersey, 1991. (IEEE 751)

Long, L.W., Analysis of Seismic Effects on Transmission Structures, IEEE Paper T 73 326-6, April 1973. (IEEE Long).

Lum, W. B., N. N. Nielson, R. Koyanagi, and A. N. L. Chui, "Damage Survey of the Kasiki, Hawaii Earthquake of November 16, 1993," Earthquake Spectra, November 1984. (Lum)

Lyver, T. D., W. H. Mueller, and L. Kempner, Jr., *Response Modification Factor, R_w, for Transmission Towers*, Research Report, Portland State University, Portland, Oregon, 1996. (Lyver)

National Center for Earthquake Engineering Research (NCEER):

The Hanshin-Awaji Earthquake of January 17, 1995—Performance of Lifelines, National Center for Earthquake Engineering Research, Technical Report NCEER-95-0015, State University of New York at Buffalo, November 3, 1995. (NCEER 95-0015)

Rural Electrical Administration (REA):

Bulletin 1724E-200, *Design Manual for High Voltage Transmission Lines*, 1992. (REA 1724).

Bulletin 65-1, *Design Guide for Rural Substations*, 1978 (REA 65-1).

Bulletin 160-2, *Mechanical Design Manual for Overhead Distribution Lines*, 1982. (REA 160)

Telecommunications Industry Association (TIA):

TIA/EIA 222F, *Structural Standards for Steel Antenna Towers and Antenna Supporting Structures*, 1996. (TIA 222)

A14.2.1 Buried Structures. This section was placed in the Appendix to Chapter 14 for the following reasons:

1. The material may serve as a starting point for continued development.
2. The comments stimulated by consideration of this section will provide valuable input so that this section may be further developed and then incorporated in the *Provisions* in the future.
3. It was determined by TS 13 and the *Provisions* Update Committee that it would be premature to incorporate this section into the *Provisions* for the 2000 edition.
4. Accepted industry standards are in the process of incorporating seismic design methodology reflecting the *Provisions*.

It is not the intent of the *Provisions* Update Committee to discourage incorporation of this section into a building code or to minimize the importance of this section. Placing this section in the appendix indicates only that this section requires further development.

Seismic forces on buried structures may include forces due to: soil displacement, seismic lateral earth pressure, buoyant forces related to liquefaction, permanent ground displacements from slope instability, lateral spread movement, fault movement, or dynamic ground displacement caused by dynamic strains from wave propagation. Identification of appropriate seismic loading conditions is dependent upon subsurface soil conditions and the configuration of the buried structure. Conditions related to permanent ground movement can often be avoided by careful site selection for isolated buried structures such as tanks and vaults. Relocation is often impractical for long buried structures such as tunnels and pipelines.

Wave propagation strains are a significant seismic force condition for buried structures if local site conditions (for instance, deep surface soil deposits with low shear wave velocities) can support the propagation of large amplitude seismic waves. Wave propagation strains tend to be most pronounced at the junctions of dissimilar buried structures (such as a pipeline connecting with a building) or at the interfaces of different geologic materials (such as a pipeline passing from rock to soft soil).

Loading conditions related to liquefaction require detailed subsurface information that can be used to assess the potential for liquefaction and, for long buried structures, the length of structure exposed to liquefaction effects. In addition, the assessment of liquefaction requires specifying an earthquake magnitude that is consistent with the definition of ground shaking. It is recommended that one refer to Chapter 7 of this C*ommentary* for additional guidance in determining liquefaction potential and seismic magnitude. Providing detailed structural design procedures in this area is beyond the scope of this document.

Loading conditions related to lateral spread movement and slope instability can be defined in terms of lateral soil pressures or prescribed ground displacements. In both cases, sufficient subsurface investigation in the vicinity of the buried structure is necessary to estimate the amount of movement, the direction of movement relative to the buried structure, and the portion of the buried structure exposed to the loading conditions. Definition of lateral spread loading conditions requires special geotechnical expertise and specific procedures in this area are beyond the scope of this document.

Defining the loading conditions for fault movement requires specific location of the fault and an estimate of the earthquake magnitude on the fault that is consistent with the ground shaking hazard in the *Provisions*. Identification of the fault location should be based on past earthquake movements, trenching studies, information from boring logs, or other accepted fault identification techniques. Defining fault movement conditions requires special seismological expertise. Additional guidance can be found in the Chapter 7 of this *Commentary*.

It may not be practically feasible to design a buried structure to resist the effects of permanent ground deformation. Alternative approaches in such cases may include relocation to avoid the condition, ground improvements to reduce the loads, or implementing special procedures or design features to minimize the impact of damage (such as remote controlled or automatic isolation valves that provide the ability to rapidly bypass damage or post-earthquake procedures to expedite repair). The goal of providing procedures or design features as an alternative to designing for the seismic loadings is to change the hazard and function classification of the buried structure such that it is not classified as Seismic Use Group II or III.

It is recommended that one refer to Chapter 7 of this C*ommentary* for additional guidance in determining liquefaction potential and determining seismic magnitude.

Buried structures are subgrade structures such as tanks, tunnels, and pipes. Buried structures that are designated as Seismic Use Group II or III, or are of such a size or length to warrant special seismic design as determined by the registered design professional, must be identified in the geotechnical report.

Buried structures must be designed to resist minimum seismic lateral forces determined from a substantiated analysis using approved procedures. Flexible couplings must be provided for buried structures requiring special seismic considerations where changes in the support system, configuration, or soil condition occur.

The requirement for and value of flexible couplings should be determined by the "properly substantiated analysis and approved procedures." It is assumed that the need for flexible couplings refers to buried piping or conduits. The prior wording of Sec. A14.2.3 was far too broad in requiring flexible couplings where changes in the support system, configuration or soil condition occur. These broad requirements could result in flexible couplings installed at locations where permanent ground displacement is expected or at transitions between aboveground supported pipe and buried pipe. As currently available flexible couplings are not generally designed to match the ultimate strength properties of the piping or conduit, the prior requirements potentially introduce a weak point in the piping or conduit system. The original focus of the prior requirements was penetrations of buried service lines into a building or other structure. Properly designed flexible couplings can be an effective means to limit forces at connections to buried structures. However, special care is needed to make sure the design loads and displacements are adequately specified. There are several other alternative to providing sufficient flexibility at connections to buried structures that are more robust in terms of margin above their design levels.