Chapter 1 Commentary

GENERAL PROVISIONS

Chapter 1 sets forth general requirements for applying the analysis and design provisions contained in Chapters 2 through 14 of the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*. It is similar to what might be incorporated in a code as administrative regulations.

Chapter 1 is designed to be as compatible as possible with normal code administrative provisions (especially as exemplified by the three national model codes), but it is written as the guide to use of the rest of the document, not as a regulatory mechanism. The word "shall" is used in the *Provisions* not as a legal imperative, but simply as the language necessary to ensure fulfillment of all the steps necessary to technically meet a minimum standard of performance.

It is important to note that the *Provisions* is intended to serve as a resource document for use by any interested member of the building community. Thus, some users may alter certain information within the *Provisions* (e.g., the determination of which use groups are included within the higher Seismic Use Groups might depend on whether the user concluded that the generally more-demanding design requirements were necessary). It is strongly emphasized, however, that such "tailoring" should be carefully considered by highly qualified individuals who are fully aware of all the implications of any changes on all affected procedures in the analysis and design sequences of the document.

Further, although the *Provisions* is national in scope, it presents minimum criteria. It is neither intended to nor does it justify any reduction in higher standards that have been locally established, particularly in areas of highest seismicity.

Reference is made throughout the document to decisions and actions that are delegated to an unspecified “authority having jurisdiction." The document is intended to be applicable to many different types of jurisdictions and chains of authority, and an attempt has been made to recognize situations where more than technical decision-making can be presumed. In fact, the document anticipates the need to establish standards and approval systems to accommodate the use of the document for development of a regulatory system. A good example of this is in Sec. 1.2.6, Alternate Materials and Alternate Means and Methods of Construction, where the need for well-established criteria and systems of testing and approval are recognized even though few such systems are in place. In some instances, the decision-making mechanism referred to is clearly most logically the province of a building official or department; in others, it may be a law-making body such as a state legislature, a city council, or some other state or local policy-making body. The term "authority having jurisdiction" has been used to apply to all of these entities. A good example of the need for keeping such generality in mind is provided by the California law concerning the design and construction of schools. That law establishes requirements for independent special inspection approved and supervised by the Office of the State Architect, a state-level office that does not exist in many other states.

Note that Appendix A to this *Commentary* volume presents a detailed explanation of the development of *Provisions* Maps 1 through 24 and Appendix B describes development of the U.S. Geological Survey seismic hazard maps on which the *Provisions* maps are based. An overview of the Building Seismic Safety Council (BSSC) and its activities appears at the end of the volume.

1.1 PURPOSE: The goal of the *Provisions* is to present criteria for the design and construction of new structures subject to earthquake ground motions in order to minimize the hazard to life for all structures, to increase the expected performance of structures having a substantial public hazard due to occupancy or use as compared to ordinary structures, and to improve the capability of essential facilities to function after an earthquake. To this end, the *Provisions* provides the minimum criteria considered prudent for the protection of life safety in structures subject to earthquakes. The *Provisions* document has been reviewed extensively and balloted by the architectural, engineering, and construction communities and, therefore, it is a proper source for the development of building codes in areas of seismic exposure.

Some design standards go farther than the *Provisions* and attempt to minimize damage as well as protect building occupants. For example, the *California Building Code* has added property protection in relation to the design and construction of hospitals and public schools. The *Provisions* document generally considers property damage as it relates to occupant safety for ordinary structures. For high occupancy and essential facilities, damage limitation criteria are more strict in order to better provide for the safety of occupants and the continued functioning of the facility.

Some structural and nonstructural damage can be expected as a result of the "design ground motions" because the *Provisions* allow inelastic energy dissipation in the structural system. For ground motions in excess of the design levels, the intent of the *Provisions* is for the structure to have a low likelihood of collapse.

It must be emphasized that absolute safety and no damage even in an earthquake event with a reasonable probability of occurrence cannot be achieved for most structures. However, a high degree of life safety, albeit with some structural and nonstructural damage, can be economically achieved in structures by allowing inelastic energy dissipation in the structure. The objective of the *Provisions* therefore is to set forth the minimum requirements to provide reasonable and prudent life safety. For most structures designed and constructed according to the *Provisions*, it is expected that structural damage from even a major earthquake would likely be repairable, but the damage may not be economically repairable.

Where damage control is desired, the design must provide not only sufficient strength to resist the specified seismic loads but also the proper stiffness to limit the lateral deflection. Damage to nonstructural elements may be minimized by proper limitation of deformations; by careful attention to detail; and by providing proper clearances for exterior cladding, glazing, partitions, and wall panels. The nonstructural elements can be separated or floated free and allowed to move independently of the structure. If these elements are tied rigidly to the structure, they should be protected from deformations that can cause cracking; otherwise, one must expect such damage. It should be recognized, however, that major earthquake ground motions can cause deformations much larger than the specified drift limits in the *Provisions*.

Where prescribed wind loading governs the stress or drift design, the resisting system still must conform to the special requirements for seismic force resisting systems. This is required in order to resist, in a ductile manner, potential seismic loadings in excess of the prescribed loads.

A proper continuous load path is an obvious design requirement for equilibrium, but experience has shown that it often is overlooked and that significant damage and collapse can result. The basis for this design requirement is twofold:

1. To ensure that the design has fully identified the seismic force resisting system and its appropriate design level and

2. To ensure that the design basis is fully identified for the purpose of future modifications or changes in the structure.

Detailed requirements for selecting or identifying and designing this load path are given in the appropriate design and materials chapters.

1.2.1 Scope: The scope statement establishes in general terms the applicability of the *Provisions* as a base of reference. Certain *structures* are exempt and need not comply:

1. Detached one- and two-family dwellings in *Seismic Design Categories* A, B, and C are exempt because they represent low seismic risks.

2. *Structures* constructed using the conventional light-frame construction requirements in Sec. 12.5 are deemed capable of resisting the *seismic forces* imposed by the *Provisions.* While specific elements of conventional light-frame construction may be calculated to be over-stressed, there is typically a great deal of redundancy and uncounted resistance in such *structures*. Detached one- and two-story wood frame dwellings have generally performed well even in regions of higher seismicity. The requirements of Sec. 12.5 are adequate to provide the safety required for such dwellings without imposing any additional requirements of the *Provisions*.

3. Agricultural storage *structures* are generally exempt from most code requirements because of the exceptionally low risk to life involved and that is the case of the *Provisions*.

4. *Structures* in areas with extremely low seismic risk need only comply with the design and detailing requirements for *structures* assigned to *Seismic Design Category* A.

The *Provisions* are not retroactive and apply only to existing *structures* when there is an *addition*, change of use, or *alteration*. As a minimum, existing *structures* should comply with legally adopted regulations for repair and rehabilitation as related to earthquake resistance. (Note: Publications such as the Seismic Rehabilitation Guidelines and Commentary- FEMA 273 &274 are available.)

The *Provisions* are not written to prevent damage due to earth slides (such as those that occurred in Anchorage, Alaska), to liquefaction (such as occurred in Niigata, Japan), or to tsunami (such as occurred in Hilo, Hawaii). It provides for only minimum required resistance to earthquake ground-shaking, without settlement, slides, subsidence, or faulting in the immediate vicinity of the *structure*.

1.2.2 Additions: Additions that are structurally independent of an existing structure are considered to be new structures required to conform with the *Provisions*. For additions that are not structurally independent, the intent is that the addition as well as the existing structure be made to comply with the *Provisions* except that an increase of up to 5 percent of the mass contributing to seismic forces is permitted in any elements of the existing structure without bringing the entire structure into conformance with the *Provisions*. Additions also shall not reduce the lateral force resistance of any existing element to less than that required for a new structure.

1.2.3 Change of Use: When a change in the use of a *structure* will result in the *structure* being reclassified to a higher *Seismic Use Group*, the existing *structure* must be brought into compliance with the requirements of the *Provisions* as if it were a new *structure*. *Structures* in higher *Seismic Use Groups* are intended to provide a higher level of safety to occupants and in the case of *Seismic Use Group* III be capable of performing their safety-related function after a seismic event. An exception is allowed when the change is from *Seismic Use Group* I to *Seismic Use Group* II where S_{DS} is less than 0.3. The expense that may be necessary to upgrade such as structure because of a change in the Seismic Use Group cannot be justified for structures located in regions with low seismic risk.

1.2.4 Alterations: *Alterations* include all significant modifications to existing *structures* that are not classified as an *addition*. No reduction in strength of the *seismic-force-resisting system* or stiffness of the *structure* shall result from an *alteration* unless the altered *structure* is determined to be in compliance with the *Provisions*. Like *additions*, an increase of not greater than 5 percent of the mass contributing to *seismic forces* is permitted in any structural element of the existing *structure* without bringing the entire *structure* into conformance with the *Provisions*.

The cumulative effects of *alterations* and *additions* should not increase the *seismic forces* in any structural element of the existing *structure* by more than 5 percent unless the capacity of the element subject to the increased *seismic forces* is still in compliance with the *Provisions*.

1.2.5 Alternate Materials and Alternate Means and Methods of Construction: It is not possible for a design standard to provide criteria for the use of all possible materials and their combinations and methods of construction either existing or anticipated. While not citing specific materials or methods of construction currently available that require approval, this section serves to emphasize the fact that the evaluation and approval of alternate materials and methods require a recognized and accepted approval system. The requirements for materials and methods of construction contained within the document represent the judgment of the best use of the materials and methods based on well-established expertise and historical seismic performance. It is important that any replacement or substitute be evaluated with an understanding of all the ramifications of performance, strength, and durability implied by the *Provisions*.

It also is recognized that until needed approval standards and agencies are created, authorities having jurisdiction will have to operate on the basis of the best evidence available to substantiate any application for alternates. If accepted standards are lacking, it is strongly recommended that applications be supported by extensive reliable data obtained from tests simulating, as closely as is practically feasible, the actual load and/or deformation conditions to which the material is expected to be subjected during the service life of the structure. These conditions, where applicable, should include several cycles of full reversals of loads and deformations in the inelastic range.

1.3 SEISMIC USE GROUPS: The expected performance of *structures* shall be controlled by assignment of each *structure* to one of three *Seismic Use Groups*. *Seismic Use Groups* are categorized based on the occupancy of the *structures* within the group and the relative consequences of earthquake induced damage to the *structures.* The *Provisions* specify progressively more conservative strength, drift control, system selection and detailing requirements for *structures* contained in the three groups, in order to attain minimum levels of earthquake performance suitable to the individual occupancies.

In previous editions of the *Provisions*, this categorization of *structures*, by occupancy, or use, was termed a Seismic Hazard Exposure Group. The name *Seismic Use Group* was adopted in the 1997 *Provisions* as being more representative of the definition of this classification. Seismic hazard relates to the severity and frequency of ground motion expected to affect a *structure*. Since *structures* contained in these groups are spread across the various zones of seismicity, from high to low hazard, the groups do not really relate to hazard. Rather the groups, categorized by occupancy or use, are used to establish design criteria intended to produce specific types of performance in design earthquake events, based on the importance of reducing structural damage and improving life safety.

In terms of post-earthquake recovery and redevelopment, certain types of occupancies are vital to public needs. These special occupancies were identified and given specific recognition. In terms of disaster preparedness, regional communication centers identified as critical emergency services should be in a higher classification than retail stores, office buildings, and factories.

Specific consideration is given to Group III, essential facilities required for post-earthquake recovery. Also included are *structures* that contain substances, that if released into the environment, are deemed to be hazardous to the public. The 1991 Edition included a flag to urge consideration of the need for utility services after an earthquake. It is at the discretion of the authority having jurisdiction which *structures* are required for post-earthquake response and recovery. This is emphasized with the term "designated" before many of the *structures* listed in Sec. 1.3.1. Using Item 3, “designated medical facilities having emergency treatment facilities” as an example, the authority having jurisdiction should inventory medical facilities having emergency treatment facilities within the jurisdiction and designate those to be required for post-earthquake response and recovery. In a rural location where there may not be a major hospital, the authority having jurisdiction may choose to require outpatient surgery clinics to be designated Group III *structures*. On the other hand, these same clinics in a major jurisdiction with hospitals nearby may not need to be designated Group III *structures*.

Group II *structures* are those having a large number of occupants and those where the occupants ability to exit is restrained. The potential density of public assembly uses in terms of number of people warrant an extra level of care. The level of protection warranted for schools, day care centers, and medical facilities is greater than the level of protection warranted for occupancies where individuals are relatively self-sufficient in responding to an emergency.

Group I contains all uses other than those excepted generally from the requirements in Sec. 1.2. Those in Group I have lesser life hazard only insofar as there is the probability of lesser numbers of occupants in the *structures* and the *structures* are lower and/or smaller.

In *structures* with multiple uses, the 1988 Edition of the *Provisions* required that the *structure* be assigned the classification of the highest group occupying 15 percent or more of the total area of the *structure*. This was changed in the 1991 Edition to require the *structure* to be assigned to the highest group present. These requirements were further modified to allow different portions of a *structure* to be assigned different *Seismic Use Groups* provided the higher group is not negatively impacted by the lower group. When a lower group impacts a higher group, the higher group must either be seismically independent of the other, or the two must be in one *structure* designed seismically to the standards of the higher group. Care must be taken, however, for the case in which the two uses are seismically independent but are functionally dependent. The fire and life-safety requirements relating to exiting, occupancy, fire-resistive construction and the like of the higher group must not be reduced by interconnection to the lower group. Conversely, one must also be aware that there are instances, although uncommon, where certain fire and life-safety requirements for a lower group may be more restrictive than those for the higher group. Such assignments also must be considered when changes are made in the use of a *structure* even though existing *structures* are not within the scope of the *Provisions*.

Consideration has been given to reducing the number of groupings by combining Groups I and II and leaving Group III the same as is stated above; however, the consensus of those involved in the *Provisions* development and update efforts to date is that such a merging would not be responsive to the relative performance desired of *structures* in these individual groups.

Although the *Provisions* explicitly require design for only a single level of ground motion, it is expected that *structures* designed and constructed in accordance with these requirements will generally be able to meet a number of performance criteria, when subjected to earthquake ground motions of differing severity. The performance criteria discussed here were jointly developed during the BSSC Guidelines and Commentary for Seismic Rehabilitation of Buildings Project (ATC, 1995) and the Structural Engineers Association of California *Vision 2000* Project (SEAOC, 1995). In the system established by these projects, earthquake performance of *structures* is defined in terms of several standardized performance levels and reference ground motion levels. Each performance level is defined by a limiting state in which specified levels of degradation and damage have occurred to the structural and nonstructural building *components*. The ground motion levels are defined in terms of their probability of exceedance.

Four performance levels are commonly described as meaningful for the design of *structures*. Although other terminology has been used in some documents, these may respectively be termed the operational, immediate occupancy, life safety, and collapse prevention levels. Of these, the operational level represents the least level of damage to the *structure*. *Structures* meeting this level when responding to an earthquake are expected to experience only negligible damage to their structural systems and minor damage to nonstructural systems. The *structure* will retain nearly all of its pre-earthquake strength and stiffness and all mechanical, electrical, plumbing, and other systems necessary for the normal operation of the *structure* are expected to be functional. If repairs are required, these can be conducted at the convenience of the occupants. The risk to life safety during an earthquake in a *structure* meeting this performance level is negligible. Note, that in order for a *structure* to meet this level, all utilities required for normal operation must be available, either through standard public service or emergency sources maintained for that purpose. Except for very low levels of ground motion, it is generally not practical to design *structures* to meet this performance level.

The immediate occupancy level is similar to the operational level although somewhat more damage to non-structural systems is anticipated. Damage to the structural systems is very slight and the *structure* retains all of its pre-earthquake strength and nearly all of its stiffness. Nonstructural elements, including ceilings and cladding, but also mechanical and electrical *components*, remain secured and do not represent hazards. Exterior nonstructural wall elements and roof elements continue to provide a weather barrier, and be otherwise serviceable. The *structure* remains safe to occupy, however, some repair and clean-up is probably required before the *structure* can be restored to normal service. In particular, it is expected that utilities necessary for normal function of all systems will not be available, although those necessary for life safety systems would be provided. Some equipment and systems used in normal function of the *structure* may experience internal damage due to shaking of the *structure*, but most would be expected to operate if the necessary utility service was available. Similar to the operational level, the risk to life safety during an earthquake in a *structure* meeting this performance level is negligible. Structural repair may be completed at the occupants convenience, however, significant nonstructural repair and cleanup is probably required before normal function of the *structure* can be restored.

At the life safety level, significant structural and nonstructural damage has occurred. The *structure* may have lost a substantial amount of its original lateral stiffness and strength but still retains a significant margin against collapse. The *structure* may have permanent lateral offset and some elements of the *seismic-force resisting system* may exhibit substantial cracking, spalling, yielding and buckling. Nonstructural elements of the *structure*, while secured and not presenting falling hazards, are severely damaged and can not function. The *structure* is not safe for continued occupancy until repairs are instituted as strong ground motion from aftershocks could result in life threatening damage. Repair of the *structure* is expected to be feasible, however, it may not be economically attractive to do so. The risk to life during an earthquake, in a *structure* meeting this performance level is very low.

At the near collapse level a *structure* has sustained nearly complete damage. The *seismic-force resisting system* has lost most of its original stiffness and strength and little margin remains against collapse. Substantial degradation of the structural elements has occurred including extensive cracking and spalling of masonry and concrete elements and buckling and fracture of steel elements. The *structure* may have significant permanent lateral offset. Nonstructural elements of the *structure* have experienced substantial damage and may have become dislodged creating falling hazards. The *structure* is unsafe for occupancy as even relatively moderate ground motion from aftershocks could induce collapse. Repair of the *structure* and restoration to service is probably not practically achievable.

The design ground motion contained in the *Provisions* is taken as two-thirds of the *maximum considered earthquake ground motion*. Such ground motion may have a return period varying from a few hundred years to a few thousand years, depending on the regional seismicity. It is expected that *structures* designed in accordance with the requirements for Group I would achieve the life safety or better performance level for these ground motions. *Structures* designed in accordance with the requirements for Group III should be able to achieve the Immediate Occupancy or better performance level for this ground motion. *Structures* designed to the requirements for Group II would be expected to achieve performance better than the life safety level but perhaps less than the immediate occupancy level for this ground motion.

While the design ground motion represents a rare earthquake event, it may not be the most severe event that could ever effect a site. In zones of moderate seismicity, it has been common practice in the past to consider ground motion with a 98 percent chance of non-exceedance in 50 years, or an average return period of 2,500 years, as being reasonably representative of the most severe ground motion ever likely to effect a site. This earthquake has been variously termed a maximum credible earthquake, maximum capable event and, most recently, a *maximum considered earthquake*. The recent terminology is adopted here in recognition that ground motion of this probability level is not the most severe motion that could ever effect the site, but is considered sufficiently improbable that more severe ground motions need not practically be considered. In regions near major active faults, such as coastal California, estimates of ground motion at this probability of exceedance can produce structural demands much larger than has typically been recorded in past earthquakes. Consequently, in these zones, the *maximum considered earthquake* is now commonly taken based on conservative estimates of the ground motion from a deterministic event, representing the largest magnitude event that the nearby faults are believed capable of producing.

It is expected that *structures* designed to the requirements for Group I would be capable of responding to the *maximum considered earthquake* at a near collapse or better performance level. *Structures* designed to the requirements for Group III should be capable of responding to such ground motions at the life safety level. *Structures* designed and constructed to the requirements for Group II *structures* should be capable of responding to *maximum considered earthquake ground motions* with a performance intermediate to the near collapse and life safety levels.

In zones of high seismicity, *structures* may experience strong motion earthquakes several times during their lives. It is also important to consider the performance expected of *structures* for these somewhat less severe, but much more frequent, events. For this purpose, earthquake ground shaking with a 50 percent probability of non-exceedance in 50 years may be considered. Sometimes termed a maximum probable event (MPE), such ground motion would be expected to recur at a site, one time, every 72 years. *Structures* designed to the requirements for Group I would be expected to respond to such ground motion at the Immediate Occupancy level. *Structures* designed and constructed to either the Group II or Group III requirements would be expected to perform to the Operational level for these events. This performance is summarized in Figure C1.3.

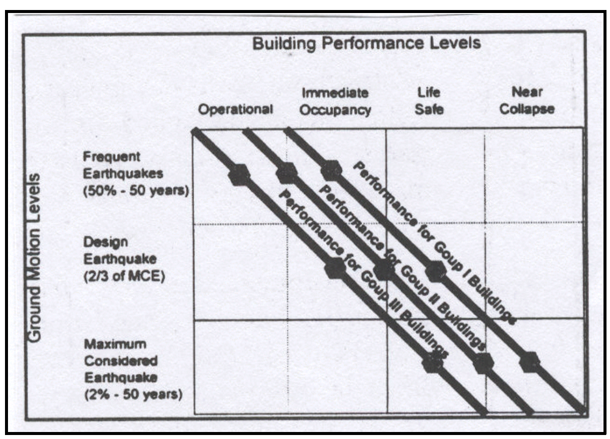

Figure C1.3 Expected building performance

It is important to note that while the performance indicated in Figure C1.3 is generally indicative of that expected for *structures* designed in accordance with the *Provisions*, there can be significant variation in the performance of individual *structures* from these expectations. This variation results from individual site conditions, quality of construction, structural systems, detailing, overall configuration of the *structure*, inaccuracies in our analytical techniques and a number of other complex factors. As a result of these many factors, and intentional conservatism contained in the *Provisions*, most *structures* will perform better than indicated in the figure and others will not perform as well.

1.3.5 Seismic Use Group III Structure Access Protection: This section establishes the requirement for access protection for *Seismic Use Group* III *structures*. There is a need for ingress/egress to those *structures* that are essential post-earthquake facilities and this shall be considered in the siting and design of the *structure*.

1.4 OCCUPANCY IMPORTANCE FACTOR: The concept of an *occupancy importance factor* for structural systems has been included in the *Uniform Building Code* for many years, however, it was first adopted into the 1997 Edition of the *Provisions.* The inclusion of the *occupancy importance factor* is one of several requirements included in this edition of the *Provisions* where there are attempts to control the seismic performance capability of *structures* in the different *Seismic Use Groups*. Specifically, the *occupancy importance factor* modifies the R coefficients used to determine minimum design *base shear* forces. *Structures* assigned *occupancy importance factors* greater than 1.0 must be designed for larger *base shear* forces. As a result, these *structures* are expected to experience lower ductility demands than *structures* designed with lower *occupancy importance factors* and, hence, these *structures* would be expected to sustain less damage. The *Provisions* also include requirements that attempt to limit vulnerability to structural damage by specifying more stringent drift limits for *structures* in *Seismic Use Groups* of higher risk. Further discussion of these concepts is found in *Commentary* Sec. 5.2. and 5.2.8.