Briefing Paper 6

Seismic Code Requirements for Anchorage of Nonstructural Components

Part A: Performance Implications of Evolving Codes

Introduction

Briefing Paper 6, *Seismic Code Requirements for Anchorage of Nonstructural Components*, consists of two parts. This Part A provides a brief history of how earthquake-resisting provisions of the *Uniform Building Code* (UBC) have evolved and relates those changes to the expected seismic performance of nonstructural building components in older buildings. Part B describes current trends in the codes for anchorage of nonstructural components and provides design examples based on the 1997 UBC provisions.

With an understanding of building code changes over the years, it is possible to develop a general sense of the earthquake resistance of existing buildings designed and constructed with such codes. This understanding is particularly useful for the evaluation of nonstructural components and systems, which can be easily upgraded through retrofits.

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The UBC, which was first published in 1927 and is updated every three years by the International Conference of Building Officials (ICBO), contains provisions that pertain to the seismic design of both structural components and nonstructural components. The UBC is a key element in the mitigation of nonstructural component seismic hazards because it already provides the basis for the seismic requirements of local-jurisdictions for new building design in California and other seismically active states, particularly in the western United States.

Requirements for seismic retrofit (as opposed to new design) have not yet been standardized, but are expected to follow generally the requirements for seismic design of new buildings. For example, the recently completed FEMA-funded *NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, which were developed for use on a voluntary basis and are expected to be used widely over the next several decades, have adopted requirements for nonstructural components similar to those in the 1997 UBC.

While the UBC contains numerous provisions that govern the seismic performance of buildings, this Part A historical perspective is limited to those parameters that have the greatest influence on the performance of nonstructural components: (1) seismic base shear; (2) nonstructural component seismic force factor; (3) interstory drift; (4) requirements for cladding connections; and (5) requirements for building separation.

The sections that follow include figures that show the evolution of UBC requirements from 1927 through 1994. The 1997 UBC, not plotted in the figures, incorporated a significant change from a working stress design to a strength design basis. Calibration of the recast equations confirm that final designs using the 1994 and 1997 UBC remain essentially the same. See Briefing Paper 6, Part B, for more information.

Evolution of Base Shear Requirements

The base shear requirements in the various editions of the UBC effectively dictate how much seismic strength a structure must have as a whole. This parameter is important because buildings designed for a relatively low horizontal base shear may sustain significant damage to the building structural system when severe earthquake ground motion occurs. Partial structural collapse or permanent deformation, should it occur, is likely to cause damage to the building nonstructural components. A horizontal base shear requirement expressed as a percent of gravity and related to building mass was introduced in the first (1927) edition of the UBC. Significant changes in base shear requirement occurred in the 1946, 1961 and 1976 editions of the UBC (see Figure 1), including the introduction of an importance factor, I_p, which specifies higher force levels for important buildings, such as hospitals and emergency response facilities. The increases in the base shear requirement were accompanied by the introduction of other detailed seismic provisions in 1976 and 1988.

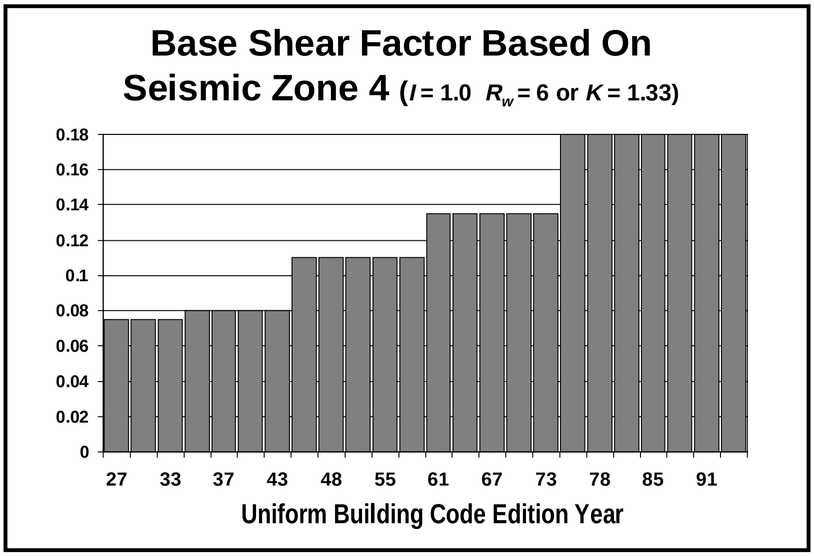

Figure 1. Changes in UBC seismic base shear requirements for shear-wall buildings in seismic zone 4 (highest zone) with an Importance Factor of 1.0.

Evolution of Seismic Force Requirement for Nonstructural Building Components

The seismic force factor for nonstructural and structural components in the UBC (e.g., f_p in the 1994 edition) governs the seismic strength of nonstructural building components. The purpose of the factor is to reduce the risk of nonstructural component failure (that is, the architectural, mechanical, and electrical components). Examples of components that are designed in accordance with this factor are chimneys, parapets, exterior cladding, partitions, ceilings, light fixtures, ornamentation, boilers, fans, elevators, and sprinkler systems.

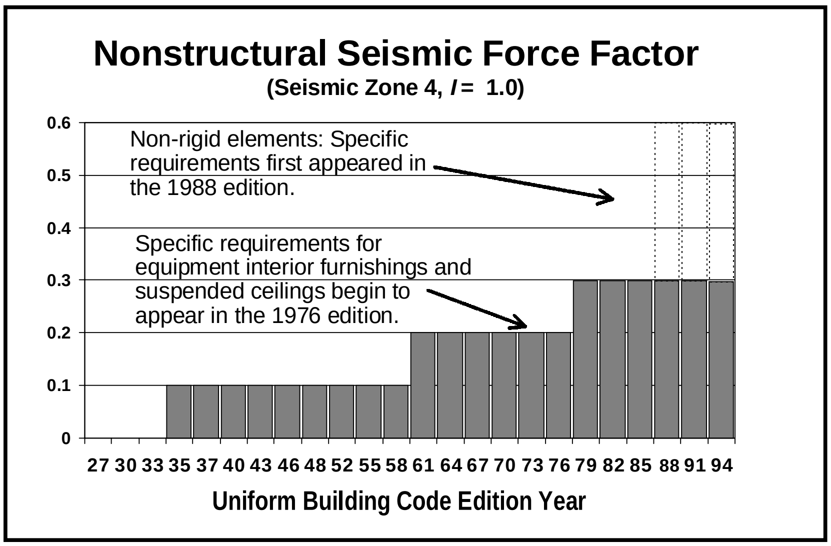

Figure 2. Changes in UBC seismic force factor for buildings in seismic zone 4 with an Importance Factor of 1.0.

Figure 2 shows how the seismic force factor has increased since its introduction. The requirements in the early editions were not specific; nonstructural components generally did not receive the full attention of design and construction professionals until the 1970s. Changes in the 1979 edition of the UBC signify an important upgrade of the seismic design code. The 50-percent increase in the force requirement was essentially an implicit acknowledgment that the designs under previous editions may have been seriously inadequate. Similar changes relating to "non-rigid elements" occurred in the 1988 edition. This change resulted from a greater understanding of an earthquake's dynamic effects on flexible or flexibly mounted nonstructural components.

Evolution of Drift Requirements

The primary objective of the interstory drift requirement (e.g., Section 1628.8 in the 1994 UBC) is to limit structural instability due to the P-delta effect that occurs with large lateral deflection. Drift or lateral movement under earthquake loading is also correlated strongly with nonstructural component damage. The greater the drift, the greater the likelihood of nonstructural damage during an earthquake. Because nonstructural components in older buildings (including cladding, windows, doors, and interior wall finishes) are often not designed to accommodate the extent of structural movement that is possible in older buildings, they may experience severe damage. Figure 3 illustrates the history of this requirement. Although the importance of drift was known for many years, specific requirements in the UBC were not introduced until 1976. Older flexible buildings have a greater likelihood of nonstructural damage due to the absence of limits for seismic movement of the structural system.

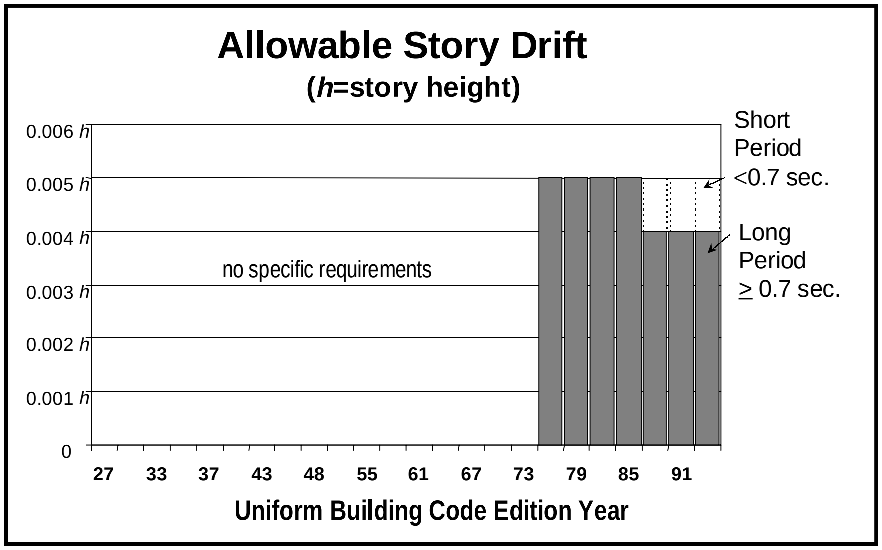

Figure 3. Changes in UBC interstory drift requirements.

Evolution of Deformation Requirements

Recognizing that structures will deform under earthquake loading, this UBC requirement (e.g., Section 1631.2.4 of the 1994 UBC) reduces damage to nonstructural components by requiring them to accommodate movement. From an economic loss perspective, this requirement probably has the greatest impact on the design of exterior cladding. The cost of exterior cladding is an important building cost. Damage to a building envelope or its weatherproofing can also lead to losses from water infiltration. Figure 4 shows the introduction of this requirement in 1967, with a major change in 1976. Buildings constructed before the 1967 UBC may be at higher risk for cladding damage.

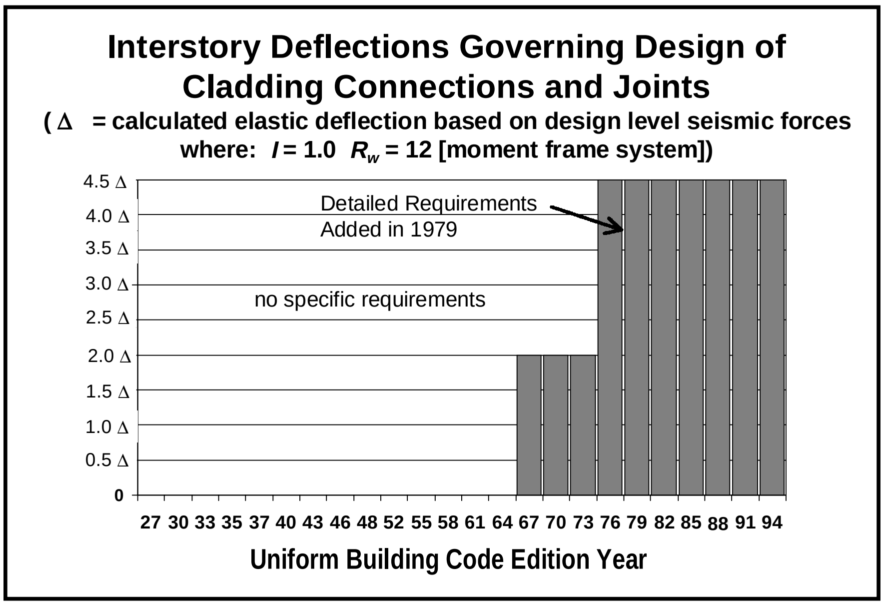

Figure 4. Changes in UBC exterior element deflection limitsfor moment frame buildings with an Importance factor of 1.0.

Evolution of Building Separation Requirements

This provision requires buildings to be separated to reduce pounding damage during earthquakes (e.g., Section 1631.2.11 in the 1994 UBC). As early as 1952, the UBC included a nonspecific requirement to provide building separation. From the 1961 to 1985 editions, structures were required to provide separation "to avoid contact under deflection from seismic action." A professional guideline recommended that a separation of 3/*K* times the calculated deflection be provided, where *K* was a horizontal force factor used in calculating design base shear. The 1988 UBC integrated this guideline by requiring the separation to be to $3(R_w / 8)$, here R_w was a structural response modification factor approximately equal to $8/K$. In effect, the requirement specified the separation to be three times the design deformation.

Because the earlier requirements were not specific, buildings built under pre-1988 editions of the UBC may still be subject to pounding damage to both structural and nonstructural systems.

General Conclusions

For nonstructural components in most ordinary buildings, there appears to be a period of greatly increased designer concern for seismic detailing starting in about 1976. Seismic detailing appears to improve dramatically until about 1990. After that, improvements in seismic design have been more incremental.

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Briefing papers in this series are concise, easy-to-read summary overviews of important issues and topics that facilitate the improvement of earthquake-resistant building design and construction quality.

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