Briefing Paper 6

Seismic Code Requirements for Anchorage of Nonstructural Components

Part B: Design Example Using Current UBC Requirements

Introduction

Briefing Paper 6, *Seismic Code Requirements for Anchorage of Nonstructural Components*, consists of two parts. 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. This Part B compares the 1994 *Uniform Building Code* requirements with those contained in the 1997 UBC, and provides design examples based on the 1997 UBC provisions.

Recent Developments in Seismic Codes for Nonstructural Components

As summarized in Part A of this Briefing Paper, the seismic requirements for anchorage of nonstructural building components in the *Uniform Building Code* have been incrementally increasing since their introduction in 1927. The seismic provisions in the 1994 and earlier editions of the UBC were based on allowable stress design. In 1997, the UBC seismic provisions were revised from an allowable stress design basis to a strength design basis. The change occurred because the UBC adopted the requirements specified in the FEMA-funded National Earthquake Hazards Reduction Program (NEHRP) *Recommended Provisions for the Development of Seismic Regulations for New Buildings* (hereinafter called *NEHRP Recommended Provisions for New Buildings*), which had been developed on a strength design basis. As a result, engineers and architects who were familiar with the design earthquake forces found in earlier editions of the UBC were required to determine design earthquake forces on a strength basis.

Current building codes and standards require site-specific considerations and yield larger forces when the building is founded on softer soils or near faults.

In addition, the determination of earthquake design forces in the 1997 UBC and other recent model building codes and standards have become more complicated. The 1997 UBC, the 1997 *NEHRP Recommended Provisions for New Buildings*, and the 1997 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* for example, require site-specific considerations and yield larger forces when the building is founded on softer soils or near active faults. In addition, larger forces are required at higher elevations in the building, consistent with measured in-structure earthquake acceleration response. It is expected that this additional complexity will result in better and more cost-effective protection of nonstructural components.

Following is a comparison of the 1994 UBC allowable stress design and the 1997 UBC strength design provisions for anchorage of nonstructural components.

1994 UBC Allowable Stress Design Force Provisions

The seismic provisions of the 1994, and earlier, editions of the UBC were based principally on the recommendations of the Seismology Committee of the Structural Engineers Association of California (SEAOC), as summarized in the SEAOC "Blue Book". The pertinent earthquake design provisions for nonstructural components are given in the following equation:

$$F_p = Z I_p C_p W_p \qquad (1)$$

where:

F_p = Total allowable-stress design lateral seismic force on nonstructural component

Z = Seismic zone factor, tabulated, dependent on seismic zone

I_p = Seismic importance factor, tabulated, dependent on occupancy category

C_p = Horizontal force factor, tabulated, either 0.75 or 2.0, depending on the specific component, with cantilevered components having a value of 2.0

W_p = Nonstructural component weight

1997 UBC Strength Design Force Provisions

The design force provisions of the 1997 UBC are based on strength instead of allowable stress. The pertinent earthquake design provisions for nonstructural components are given in the equations below:

$$F_p = 4.0C_a I_p W_p \quad (2)$$

$$F_p(\text{minimum}) = 0.7C_a I_p W_p \quad (3)$$

$$F_p(\text{alternative}) = \frac{a_p C_a I_p}{R_p}\left(1 + 3\frac{h_x}{h_r}\right)W_p \quad (4)$$

where:

F_p = Total strength design lateral seismic force on nonstructural component

C_a = Seismic coefficient, tabulated, dependent on the seismic zone and site-specific soil profile type

I_p = Importance factor, tabulated, dependent on occupancy category

W_p = Weight of nonstructural component

a_p = Component amplification factor, tabulated, dependent on nonstructural component flexibility, with a value of 1.0 for rigid components (or with a fundamental period of vibration equal to or less than 0.06 seconds), and a value of 2.5 for flexible components, flexibly attached.

R_p = Component Response Modification factor, tabulated, dependent on nonstructural component's energy-absorption capability, with a value of 1.0 for fasteners anchoring exterior elements and ranging from 1.5 for nonductile components like shallow anchors to a maximum of 4.0 for very ductile components like (steel) storage racks.

h_x = Height above average grade to level of nonstructural component attachment

h_r = Height above average grade to roof level

The values for a_p, C_a, and R_p are taken from the 1994 NEHRP *Recommended Provisions for New Buildings*, with some modifications. The height-above-grade factor $\left(1+3\frac{h_x}{h_r}\right)$, is a simplification from the 1994 *NEHRP Recommended Provisions for New Buildings*.

Design Example

The following is an example design calculation using the 1997 UBC. The example component is a package HVAC unit mounted on the roof, with and without vibration isolators (Figure 1). The building is on soil profile S_D in Seismic Zone 4 and is not in a near-source location (i.e., N_a =1.0 in Table 16-S).

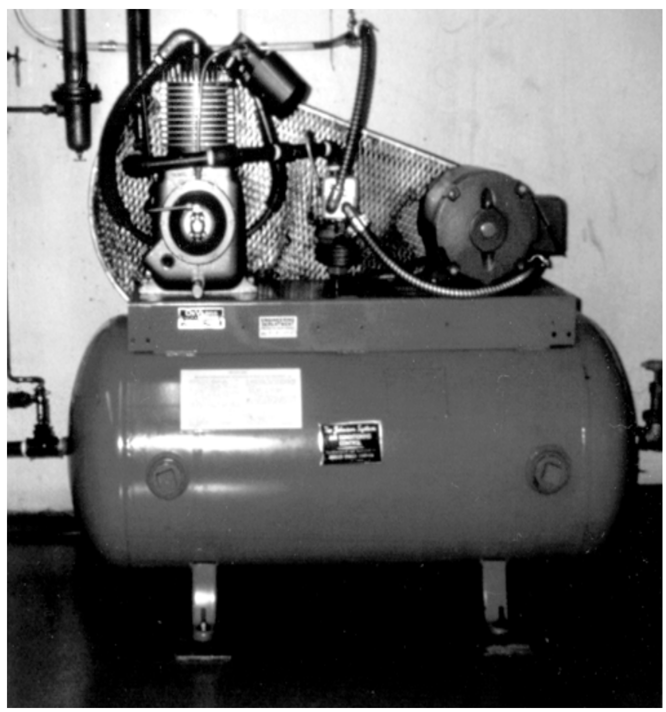

Figure 1. Example HVAC unit mounted on roof.

The 1997 UBC requires the elevation of the element, component or equipment to be specified in relationship to the base of the building. Equipment and other components located close to the roof level, and especially those located on the roof, have higher anchorage force demands than those located at lower levels. The design forces for this roof-mounted equipment are calculated for different sets of assumptions.

Case 1: Equipment Mounted on Vibration Isolators.

$h_x / h_r = 1.0$;

$I_p = 1.0$;

$a_p = 2.5$ from footnote 14 of Table 16-O;

$R_p = 1.5$ from footnote 14 of Table 16-O;

$C_a = 0.44$

$F_p = (2.5 \times 0.44 \times 1.0 / 1.5) \times (1 + 3)\, W_p$ (from equation 3 above)

$F_p = 2.933\, W_p > 4.0\, C_a$ (maximum; from equation 2 above)

$\therefore\; F_p(\text{max}) = 4.0\, C_a\, W_p = 1.76\, W_p$

Conversion to an allowable-stress design force is made by dividing the ultimate strength value by 1.4:

$$F_p / 1.4 = 1.26\, W_p.$$

This is 2.1 times the 1994 UBC requirement of $F_p = 0.6\, W_p$.

Case 2: Non-Isolated Equipment

For this case the equipment is not vibration-isolated and is considered a rigid component.

$h_x / h_r = 1.0$

$I_p = 1.0$,

$a_p = 1.0$ from Table 16-O

$R_p = 3.0$ from Table 16-O

$C_a = 0.44$

$F_p = (1.0 \times 0.44 \times 1.0 / 3.0) \times (1+ 3)$ (from equation 3 above)

$F_p = 0.59\, W_p$

Converting this to an allowable-stress design force: $F_p / 1.4 = 0.42\, W_p$

This is 1.4 times the 1994 UBC calculation of $F_p = 0.3\, W_p$.

Case 3: Flexible Equipment

The equipment is defined as flexible, which means its fundamental period is greater than 0.06 seconds, and is anchored at a point below its center of mass. The anchorage force then increases as follows:

$h_x / h_r = 1.0$

$I_p = 1.0$,

$a_p = 2.5$ from Table 16-O

$R_p = 3.0$ from Table 16-O

$C_a = 0.44$

$F_p = (2.5 \times 0.44 \times 1.0 / 3.0) \times (1 + 3)$ (from equation 3 above)

$F_p = 1.47\, W_p$

Converting this to an allowable stress design force: $F_p / 1.4 = 1.05\, W_p$

This is 1.75 times the $F_p = 0.6\, W_p$ for the 1994 UBC. Comparing Case 2 with Case 3, it is clear that accurately defining a component's fundamental period is essential, because it can make a drastic change in its anchorage requirement.

References

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About this Briefing Paper Series

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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