BCA Toolkit Seismic Structural Module Methodology Update

A Bridge Between ASCE 41-17 and HAZUS-OSHPD

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FEMA

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Executive Summary

FEMA retained Ideation, Inc., to develop an updated seismic methodology to be implemented in the BCA Toolkit. The new methodology will simplify and improve the seismic structural module of the BCA Toolkit. Ideation, Inc., evaluated subject matter experts and their proposed methodologies and selected ImageCat, Inc., and its proposed methodology as the scientific subject matter expert to assist with developing the updated seismic methodology.

The BCA Toolkit will be updated to implement improvements and will relieve the user of the need to have advanced HAZUS modeling expertise to represent specific buildings and their seismic weaknesses. Rather, a Professional Engineer (Civil or Structural) who has evaluated the building using the national standard for evaluation and retrofit of existing buildings (ASCE, 2017) will use a framework similar to the ASCE evaluation process to identify serious seismic deficiencies (both structural and nonstructural) found in the existing building. The BCA Toolkit will then effectively model the subject building in its pre-retrofit condition. The Professional Engineer will then specify the strengthening and stiffening that will result from the retrofit as well as the structural and nonstructural deficiencies that the retrofit will mitigate. The BCA Toolkit will then adjust the damage model to represent the post-retrofit condition. Given the site's seismic hazards, the BCA Toolkit will then compute the present value of future benefits from reduced damage, downtime, and casualties and will divide those benefits by the cost of the retrofit to calculate the benefit-cost ratio (BCR).

The BCA Toolkit will be updated by implementing an improved version of the HAZUS earthquake damage model, as documented in the 2022 California Administrative Code (CAC, 2022). HAZUS was adapted by the Office of Statewide Health Planning and Development to develop the HAZUS-OSHPD version to evaluate the life-safety of older hospitals in California. FEMA also uses HAZUS-OSHPD in its Rapid Visual Screening seismic tool, FEMA P-154 (FEMA, 2015a). HAZUS-OSHPD produces updated, FEMA-approved logic and values for capacity, fragility, and collapse parameters that are used to model existing buildings.

The updated BCA Toolkit will use evaluation procedures adapted from the national standard, ASCE 41-17 (ASCE, 2017), to assign collapse performance categories for use in HAZUS-OSHPD. Within the building evaluation procedures are a series of building evaluation statements, which an engineer uses to account for structural irregularities and other serious seismic deficiencies that cause increased damage and premature structural failures during earthquakes. In this way, a "bridge" is created between the standard building evaluation statements and the benefit-cost analysis that must be completed for retrofit projects evaluated by FEMA. In this methodology report, these building evaluation statements and the economic loss estimation procedures are extended to capture the high levels of damage, downtime, casualties, and the associated economic impacts from these defects in older buildings needing retrofit. Because a retrofit provides remedies to specific serious deficiencies, the improvement in seismic performance following retrofit will also be captured. Because the adjustments to HAZUS will be performed automatically within the BCA Toolkit, the user will not need to have detailed knowledge of HAZUS parameters or techniques. Implementing the changes described above will increase the calculated benefits, which is likely to increase the project BCRs.

To assess the impacts of implementing the changes on the cost effectiveness, ten example retrofits for sites in six cities in the western U.S. (in FEMA Region IX) were analyzed. First, BCRs were calculated using a previous version of the BCA Toolkit (V. 4.5.5) and by making expert adjustments to HAZUS inputs. Second, BCRs were calculated using the default parameters in the current version of the BCA Toolkit (V. 6.0). Third, BCRs were calculated by the updated methodology using the HAZUS-OSHPD engine in the improved BCA Toolkit. The BCRs calculated using the updated methodology (a) were higher than the BCRs calculated with expert adjustments to HAZUS inputs using a previous version (V. 4.5.5) of the BCA Toolkit, and (b) were about two to four times higher than the BCRs calculated using the current version (V. 6.0) of the BCA Toolkit that was run using default parameters.

1. Introduction and Overview

FEMA retained Ideation, Inc., to develop an updated seismic methodology to be implemented in the BCA Toolkit. The updated methodology will simplify and improve the seismic structural module of the BCA Toolkit. Ideation, Inc., evaluated subject matter experts and their proposed methodologies and selected ImageCat, Inc., and its proposed methodology as the scientific subject matter expert to assist with developing the updated seismic methodology.

BCA Toolkit users have had difficulty producing benefit-cost ratios (BCRs) greater than 1.0, even for seismic structural retrofit measures that are typically shown to be cost effective. There are many reasons for this. The HAZUS Advanced Engineering Building Module (AEBM) (FEMA, n.d.) was implemented in the BCA Toolkit in 2008; however, few Structural Engineers are sufficiently adept at modifying HAZUS capacity, fragility, or other parameters to fully capture both poor pre-retrofit performance and improved post-retrofit performance. While HAZUS experts using the BCA Toolkit may have been able to produce accurate results and higher BCRs, few others can. Most users—even engineers—have characterized the pre-retrofit vulnerability of the subject buildings quite generically by specifying the model building type (MBT), seismic design level (e.g., low-code), height class (e.g., low-rise), and occupancy type (e.g., GOV1, government office) using default HAZUS parameters. To reflect the reduced vulnerability in the post-retrofit condition, users often had simply increased the seismic design level (e.g., from low-code to moderate-code). However, this approach was too general to capture the poor seismic performance characteristics of older buildings, and it was inadequate to account for the serious seismic deficiencies present in buildings needing seismic retrofit.

The BCA Toolkit will be updated to implement improvements, with the intention of relieving users of the need to have expert knowledge of HAZUS software. Rather, a Professional Engineer (either Civil or Structural) can use the national standards for seismic evaluation and retrofit of existing buildings to assess the building in question, can propose retrofit schemes, and can work with the public agency staff to supply the appropriate inputs for the BCA Toolkit seismic structural model. As a result, the BCA Toolkit will produce improved results (BCRs).

The updated BCA Toolkit will first check if HAZUS is technically capable of performing the analysis. If HAZUS cannot perform the analysis adequately, the BCA Toolkit will recommend other methods that can be used. The updated BCA Toolkit will also ask the user to verify site stability prior to proceeding with the analysis so that structural improvements will not be undermined by foundation or other failures. The updated BCA Toolkit will use a structural vibration period (*Te*) preset and a lateral force coefficient (*Cs*) preset that are specific to each model building type, for the actual building height (i.e., number of stories) and year built. The presets will be computed using the Uniform Building Code (UBC) editions that would have been used for the original design, given the year built, original seismic zone, and soil type. These inputs will better capture the baseline performance characteristics of the building in question. The updated version of the BCA Toolkit will also use updated shaking hazards from the U.S. Geological Survey (Shumway et al., 2018).

The updated BCA Toolkit will lead the user through the process of identifying serious seismic deficiencies so that the modeling will reflect the poor seismic performance prior to retrofit. The queries used to identify these deficiencies are adapted from Evaluation Statements taken from ASCE 41-17 Standard for Seismic Evaluation and Retrofit of Existing Buildings (ASCE, 2017). These queries will provide a general screening for seismic stability, along with an evaluation of structural deficiencies that pertain to the specific model building type. The updated BCA Toolkit also will consider nonstructural weaknesses that pose risks to life-safety and that increase damage and downtime for repair. The number and severity of the identified deficiencies will serve as the basis on which to assign collapse performance categories (i.e., Baseline, Sub-base, and Ultra Sub-base) and modify structural response, structural and nonstructural damage states, and the attendant consequences for life-safety, damage, downtime, and associated costs.

The updated BCA Toolkit will implement the California Office of Statewide Health Planning and Development (OSHPD) version of HAZUS (CAC, 2022), as documented in the California Administrative Code. The OSHPD developed the HAZUS-OSHPD version for performing safety evaluations of older hospitals in California. FEMA also uses HAZUS-OSHPD for its FEMA P-154 Rapid Visual Screening for Potential Seismic Hazards (FEMA, 2015a) to identify, inventory, and screen buildings that are potentially seismically hazardous (see FEMA P-155 Supporting Documentation (FEMA, 2015b)). In HAZUS-OSHPD, the capacity, fragility, and collapse parameters have all been updated to account for collapse performance categories and the serious seismic deficiencies that cause high levels of damage, downtime, casualties, and the associated economic impacts. By using HAZUS-OSHPD, the methodology can reflect the expert development, extensive checking, and testing performed when developing FEMA P-154.

Post-retrofit modeling should conform to the specific retrofit concepts developed as part of the ASCE 41-17 *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2017) building evaluation, as well as the associated retrofit cost estimates. Because retrofits typically mitigate the identified seismic deficiencies, a building with features that place it in an Ultra Sub-Base Collapse performance category may be improved to meet a Sub-Base or even a Baseline performance category. Retrofit may also increase lateral system strength and stiffness and may reduce the seismic fragility of structural and nonstructural elements. Engineering input and judgment may still be needed to model the structure’s expected performance after retrofit, as well as estimation of retrofit costs.

2. Evaluation and Retrofit Process

The updated seismic structural module of the BCA Toolkit, i.e., the Seismic Structural Full Data Module, is intended to be used to accomplish the normal process of evaluating earthquake hazards and risks and developing retrofits as described in ASCE 41-17 *Seismic Evaluation and Retrofit of Existing Buildings*, an ASCE national standard. Every building consists of a structural system to support gravity loads and to resist horizontal (lateral) loads. The building also includes nonstructural components (e.g., architectural partitions and curtain wall system) and building service equipment such as mechanical, electrical, and plumbing systems. A seismic evaluation performed using ASCE 41 should address both the structural system and nonstructural components. The process for evaluating seismic hazards and risks and for conducting a BCA for a seismic retrofit is depicted in Figure 1.

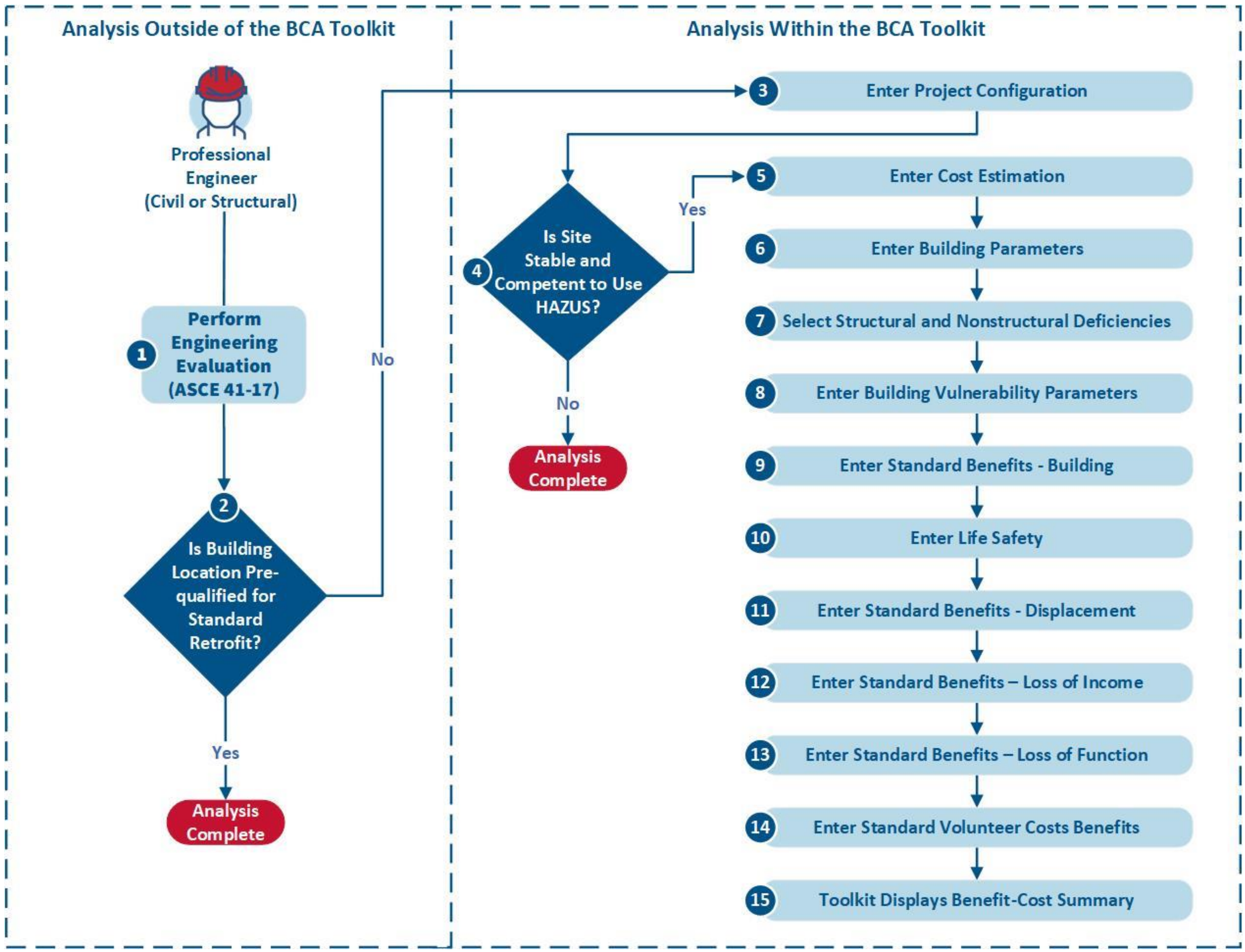

Figure 1. Process for Performing a BCA for a Seismic Retrofit Mitigation Project

As depicted in Figure 1, a Professional Engineer (Civil or Structural) who is experienced in the seismic retrofit process will complete the engineering evaluation with the assistance of other engineering and building design and construction professionals, such as architects, geotechnical engineers, contractors, etc., as needed.

The need for seismic retrofit is typically confined to older buildings. Older buildings were typically designed to meet previous seismic standards, with the result that they are found to possess weaknesses and deficiencies that place people, property, and functions at risk. Newer buildings typically meet the seismic performance objectives for buildings occupied by public agencies (see Table 3.3 in ASCE 41-17).

Some older buildings may have readily identified seismic deficiencies. For example, an older apartment building or office building (constructed before 1970) with tuck-under parking at the first story creates a soft and weak first story (i.e., Soft, Weak Open-Front (SWOF) construction) (FEMA, 2018a). In some cases, costs are relatively well-defined, such as when standard retrofit approaches apply. If a building is located within an area with a sufficiently high shaking hazard, the building may be pre-qualified for a seismic retrofit (Step 2 in Figure 1) and, therefore, it may not need further evaluation. For such buildings that are not pre-qualified for a seismic retrofit and need specific evaluation and retrofit development, the updated seismic structural module of the BCA Toolkit may be used to assess the cost-effectiveness of the retrofit (Steps 3 through 15 of Figure 1).

3. BCA Method Changes and Improvements to BCA Method

3.1. Using HAZUS-OSHPD

3.1.1. AN IMPROVED RISK "ENGINE"

In 2007, HAZUS was adapted by California's Office of Statewide Health Planning and Development (OSHPD) to analyze life-safety risks (i.e., collapse) associated with older acute-care hospital buildings. The procedures for evaluating these older hospitals were referred to as the "Express Terms," and this improved version of HAZUS, HAZUS-OSHPD, was formally adopted as a part of California Administrative Code 2022: Appendix H to Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

The procedures described in the HAZUS AEBM regulations connected HAZUS modeling with the serious deficiencies identified using evaluation statements like those in ASCE 41 (ASCE, 2017). Based upon the number and severity of deficiencies, the subject building is classified as "Baseline" (having no serious deficiencies), "Sub-baseline" or "Sub-Base" (having some serious deficiencies), or "Ultra Sub-base" (having many serious deficiencies). The HAZUS AEBM regulations also specified modified (degraded) values for the capacity curve, structural fragilities, and *K* hysteretic degradation (Kappa) that are consistent with these collapse performance categories. The HAZUS-OSHPD procedures also introduced the $\alpha 3$ (Alpha 3) Modal Shape Factor to account for nonuniform drift profiles in multistory buildings associated with "higher modes," vertical irregularities, and other deficiencies. Finally, the HAZUS AEBM procedures increased the Collapse Factor for Sub-Base and Ultra Sub-base collapse performance, which resulted in doubling and quadrupling the effects of collapse compared to the Baseline effects.

3.1.2. IMPROVEMENTS TO CONSIDER LIFE SAFETY, DAMAGE, DOWNTIME, AND NONSTRUCTURAL IMPACTS

HAZUS-OSHPD addresses life-safety, but it did not make use of HAZUS's ability to estimate financial damage, post-earthquake functionality, or downtime required for repair. In the updated seismic structural module of the BCA Toolkit, the HAZUS modifications will be extended to compute the consequences of life-safety, damage, and downtime, including the associated costs.

Furthermore, unlike the original HAZUS earthquake model (Kircher, et al., 1997), the HAZUS system that will be used for the updated BCA Toolkit correlates nonstructural damage (i.e., to nonstructural drift (NSD) and nonstructural acceleration (NSA) components) to the Complete Structural Damage State. This is done in recognition that, if a building is to be demolished, the architectural and mechanical components (i.e., NSD and NSA components) will be lost. This assumption is currently included in the production version of the HAZUS Earthquake Model (FEMA, 2020).

Finally, HAZUS will be used for the updated BCA Toolkit to consider the life-safety impacts of non-structural items, which will result in increasing the Collapse Factor for heavy nonstructural items such as unreinforced masonry full-height partitions or unsecured heavy equipment items above the ceiling.

3.2. Checking for HAZUS Competency and Site Stability

In the updated seismic structural module of the BCA Toolkit, the Toolkit will ask the user whether the HAZUS software would be competent for conducting the BCA. For cases where HAZUS would not be adequate, the BCA Toolkit will recommend other methods of analysis. The BCA Toolkit will also ask the user to verify site stability prior to proceeding so that structural improvements are not undermined by foundation or other failures. As shown in Step 4 of Figure 1, the user must answer both questions in the affirmative to be able to proceed through the updated process in the BCA Toolkit.

3.2.1. HAZUS COMPETENCY AND SITE STABILITY

HAZUS has limitations and is not competent to analyze every structure or to capture the effects of every retrofit. It is important to recognize these limitations and work within the competency of the HAZUS earthquake risk model. As an initial step, the two statements listed in Table 1 may be used to verify whether HAZUS will be eligible and competent to perform a BCA.

Examples of building types not included in HAZUS are Buckling-Restrained Braced frames, eccentric braced frames, Zipper frames, and truss frames. Examples of retrofit methods that are not readily considered in HAZUS are base isolation and supplemental dampers.

Table 1. Statements for Determining Eligibility/Competency of HAZUS

HAZUS Eligibility Concern	*Description for Eligibility*
Model Building Type (MBT) Available	There is a specific MBT in HAZUS for the specific building gravity and lateral force resisting system present in the subject building.
Number of Stories < 30	The building structure is less than 30 stories tall.

If the two statements in Table 1 are not true, then HAZUS cannot be used to conduct the BCA. Where HAZUS is not capable of or competent for conducting a BCA, other more detailed methods (for example, FEMA P-58, *Development of Next Generation Performance-Based Seismic Design Procedures for New and Existing Buildings* (FEMA, 2018b)) may be needed and should be carried out in a manner consistent with the seismic structural module of the BCA Toolkit.

3.2.2. SITE STABILITY

The three statements listed in Table 2 should be used to check for site stability.

Table 2. Site Stability Statements

Site Stability Concern	*Description of Stability*
Liquefaction	Either liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance do not exist in the foundation soils at depths within 50 ft (15.2 m) under the building, or the building foundation design mitigates such effects.
Slope Failure	Either the building site is not affected by potential earthquake-induced slope failures or rockfalls, or the building foundation design mitigates such effects.
Surface Fault Rupture	No known surface-rupturing faults affect the site and surface fault rupture or surface displacement through building foundations are not anticipated.

If the user can indicate "Compliant" for all three statements in Table 2, then the analysis can proceed. However, if an unstable site is indicated (i.e., if one or more responses to the statements in Table 2 are "Not Compliant"), then the user can be directed to conduct a full evaluation using appropriate geotechnical standards. In many cases, such a geotechnical evaluation will resolve the concern(s). If a geotechnical evaluation does not resolve the concern(s), then where the proposed retrofit will adequately address the instability, the BCA may proceed. In this case, pre-retrofit losses—and, hence, mitigation benefits—may be underestimated.

3.3. Establishing Improved Pre-sets for Lateral Force Coefficient and Structural Vibration Period

In the previous versions of the BCA Toolkit, strength, vibration period, and other values were set in an imprecise manner, based on model building type (MBT), Height Class (Low-rise, Mid-rise, or High-rise), and Seismic Design Level (High Code, Moderate Code, Low Code, or Pre-Code). The method used for setting such values in the updated seismic structural module of the BCA Toolkit will be more specific, where the actual number of stories, the design code, and the seismic zone (based on the year built and location) will be used, in addition to the MBT for values of *Cs.* Furthermore, site soils conditions would have affected the design forces used, so the new *Cs* presets will depend on the Site Class. Instead of the values of *Te* and *Cs* contained in Table A6-3 of HAZUS-OSHPD (CAC, 2022), Appendix A provides updated values for *Te* and *Cs* that should be used in the updated method.

3.3.1. LATERAL FORCE COEFFICIENT (*Cs*)

Appendix A provides detailed values for the original lateral force coefficient, *Cs*, for each model building type, detailed by height (number of stories), Site Class (soil), location/seismic zone, and year built. Under the UBC, the U.S. was divided into seismic zones, where locations having the highest shaking hazard require the highest design forces. From the first editions of the UBC (UBC, 1935) until the 1973 edition (UBC, 1973), the two highest risk seismic zones were Zone 3 and Zone 2. In the 1976 edition (UBC, 1976), Zone 4 was added, and, up until the last edition (UBC, 1997), the highest risk seismic zones were Zone 4 and Zone 3. Along with seismic zone, code design forces were generally computed as a function of the site ground conditions, so the Site Class is also important in establishing what design forces may have been used in the original design. Stiff soil (i.e., Site Class D) may be an appropriate default condition.

The detailed *Cs* values in Appendix A help set the pre-retrofit condition and are more accurate than the "Seismic Design Level" default values that were used in Version 6 of the BCA Toolkit and in prior versions. Like previous versions of the Toolkit, users will have the ability to input a *Cs* value when it is known from the original design documents or when it was estimated by a Structural Engineer.

An example of new default *Cs* values that would be used for a Steel Moment Frame (S1) for Site Class B is shown in Table 3. Table 3 is a duplicate of Table A-13 in Appendix A and shows an example of data for one Model Building Type and one Site Class. The table presents *Cs* as determined by number of stories, UBC Code edition, and Site Class for this structure type. It also shows the assumed roof height (*Hn*) and the fundamental structural period (*Te*). Note that the *Cs* value for all building heights greater than 20 stories is the same as a building height of 20 stories.

Post-retrofit design strength must be established by the Structural Engineer to meet safety and damage limitation performance objectives. In some cases, specific deficiencies may be remedied without overall strengthening, so the Lateral Force Coefficient (*Cs*) may remain unchanged. In other cases, the local jurisdiction may want the building to be strengthened to at least 75% of the current or benchmark code requirement. For post-retrofit conditions, the Cs value will be set to the maximum of 75% of the 1997 UBC Cs lookup value or the pre-retrofit *Cs* value. For the condition of a URM model building type, the post-retrofit Cs value will be a 10% increase from the initial *Cs* lookup value.

Table 3. *Te* and *Cs* Values for Model Building Type S1/S1a (Steel Moment-Frame) for Site Class B

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC Code*[2]	*Cs, UBC Code 1935-1946 Eds., UBC Zone 3*	*Cs, UBC Code 1935-1946 Eds., UBC Zone 2*	*Cs, UBC Code 1949-1958 Eds., UBC Zone 3*	*Cs, UBC Code 1949-1958 Eds., UBC Zone 2*	*Cs, UBC Code 1961-1973 Eds., UBC Zone 3*	*Cs, UBC Code 1961-1973 Eds., UBC Zone 2*	*Cs, UBC Code 1976-1985 Eds., UBC Zone 4*	*Cs, UBC Code 1976-1985 Eds., UBC Zone 3*	*Cs, UBC Code 1988-1994 Eds, UBC Zone 4*	*Cs, UBC Code 1988-1994 Eds., UBC Zone 3*	*Cs, UBC Code 1997 Ed., UBC Zone 4*	*Cs, UBC Code 1997 Ed., UBC Zone 3*
1	14	0.4	0.055	0.112	0.070	0.153	0.076	0.094	0.047	0.131	0.098	0.129	0.097	0.118	0.088
3	36	0.69	0.04	0.112	0.070	0.112	0.056	0.070	0.035	0.131	0.098	0.092	0.069	0.091	0.069
5	60	1.04	0.032	0.112	0.050	0.088	0.044	0.059	0.030	0.131	0.098	0.071	0.053	0.062	0.047
6	72	1.2	0.029	0.112	0.050	0.080	0.040	0.056	0.028	0.115	0.086	0.065	0.049	0.054	0.041
8	96	1.51	0.024	0.112	0.040	0.067	0.034	0.051	0.025	0.084	0.063	0.056	0.042	0.044	0.033
9	108	1.66	0.022	0.112	0.040	0.062	0.031	0.049	0.024	0.068	0.051	0.053	0.040	0.044	0.033
11	132	1.95	0.019	0.112	0.040	0.054	0.027	0.045	0.023	0.060	0.045	0.048	0.036	0.044	0.033
12	144	2.09	0.018	0.112	0.040	0.051	0.025	0.044	0.022	0.057	0.043	0.046	0.034	0.044	0.033
13	156	2.23	0.017	0.112	0.040	0.048	0.024	0.043	0.021	0.055	0.041	0.044	0.033	0.044	0.033
15	180	2.5	0.015	0.112	0.040	0.043	0.022	0.041	0.020	0.051	0.038	0.042	0.032	0.044	0.033
16	192	2.63	0.015	0.112	0.040	0.041	0.020	0.040	0.020	0.049	0.037	0.042	0.032	0.044	0.033
17	204	2.76	0.014	0.112	0.040	0.039	0.020	0.039	0.020	0.048	0.036	0.042	0.032	0.044	0.033
19	228	3.02	0.013	0.112	0.040	0.036	0.018	0.038	0.019	0.045	0.034	0.042	0.032	0.044	0.033
>=20	240	3.14	0.012	0.112	0.040	0.034	0.017	0.037	0.019	0.044	0.033	0.042	0.032	0.044	0.033

3.3.2. STRUCTURAL VIBRATION PERIOD (*Te*)

Appendix A also provides the structural vibration periods, *Te*, used in HAZUS-OSHPD for each model building type, for building heights from 1 to 20 stories. These same values for *Te* will be used in the updated seismic structural module of the BCA Toolkit. An example of the *Te* values that would be used for a Steel Moment Frame (S1) is shown in Table 3. Note that the *Te* values for building heights greater than 20 stories are the same as the *Te* values for a building height of 20 stories.

3.4. Accounting for Structural Deficiencies

As shown in Figure 1, a Professional Engineer (Civil or Structural) should perform at least an ASCE 41 Tier 1 seismic evaluation of the building, for both structural and nonstructural components. Then the Professional Engineer should provide seismic retrofit recommendations as appropriate and relevant. The results of that evaluation will allow the Professional Engineer to supply the responses needed for conducting a BCA and representing the pre-retrofit condition.

3.4.1. STRUCTURAL EVALUATION STATEMENTS

Structural Evaluation Statements are used to identify serious seismic deficiencies that affect the building in its pre-retrofit condition. The set of Structural Evaluation Statements used in the updated seismic structural module of the BCA Toolkit are listed in the second column of Table 4. As indicated in the third column, some of these Structural Evaluation Statements were adapted from Table 17-2, Collapse Prevention Basic Configuration Checklist, in ASCE 41-17 (ASCE, 2017), and some evaluation statements (labeled “New”) were developed by ImageCat to address the condition, connections, and horizontal diaphragms (roofs and floors). The fourth column indicates which Structural Evaluation Statements are applicable for all MBTs and which are applicable only for select MBTs. In the first column for Condition, the user should choose a response of “Compliant,” “Noncompliant with Limited Concern,” “Noncompliant with High Concern,” “Unknown,” or “Not Applicable” for each Structural Evaluation Statement. This provides a more flexible scoring system than ASCE 41-17 to allow some judgment on the severity of the deficiency and the assignment of Collapse Performance Category. In the Condition column, a response for both the pre-retrofit condition and the expected post-retrofit condition must be provided for each Structural Evaluation Statement. The last column indicates whether an evaluation statement is relevant to one-story buildings (i.e., where the statement addresses vertical irregularity in a multi-story building). If an entry of “No” is shown, the statement will not be shown for a one-story structure. This will help the process be more efficient.

The responses in the Condition column for each evaluation statement will determine what score is assigned for each statement, and the set of structural scores for the building will determine the Collapse Performance Category assigned as well as the HAZUS-OSHPD parameters. Scores are assigned to the evaluation statements for both the pre-retrofit condition and again for the improved, post-retrofit condition. For cases where serious seismic deficiencies will be remedied by the seismic retrofit, the scores will be different, and the Collapse Performance Category may improve from Ultra Sub-Base to either Sub-Base or Baseline.

Table 4. Structural Evaluation Statements for Pre-Retrofit and Post-Retrofit Conditions

Condition[1]	*Structural Evaluation Statement*	*Source*[2]	*Model Building Type(s)*	*Relevant to One-Story?*
	Load Path: The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the initial forces associated with mass of all elements of the building to the foundation.	A.2.1.1	ALL	Yes
	Adjacent Buildings: The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity.	A.2.1.2	ALL	Yes
	Mezzanines: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic force-resisting elements of the main structure.	A.2.1.3	ALL	Yes
	Weak Story: The sum of the shear strengths of the seismic force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above.	A.2.2.2	ALL	No
	Soft Story: The stiffness of the seismic force-resisting system in any story is not less than 70% of the seismic force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic force-resisting system stiffness of the three stories above.	A.2.2.3	ALL	No
	Vertical Irregularities: All vertical elements in the seismic-force- resisting system are continuous to the foundation.	A.2.2.4	ALL	No
	Geometry: There are no changes in the net horizontal dimension of the seismic force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines.	A.2.2.5	ALL	No

Condition[1]	*Structural Evaluation Statement*	*Source*[2]	*Model Building Type(s)*	*Relevant to One-Story?*
	Mass: There is no change in effective mass of more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered.	A.2.2.6	ALL	Yes
	Torsion: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension.	A.2.2.7	ALL	Yes
	Deterioration or Existing Damage: There is no significant deterioration or widespread existing damage in the elements of the gravity or lateral force resisting system. Structural modifications have not reduced the capacity to resist earthquake forces.	A.2.3	ALL	Yes
	Design, Materials, and Workmanship: The building appears to have been designed under the current seismic design code using good materials and workmanship.	New	ALL	Yes
	Connections: Connections and joints are able to develop the strength of members as needed to develop the intended strength of the connected members, and do not present a weak link in the overall seismic load-resisting or gravity systems.	New	ALL	Yes
	Horizontal Diaphragms: Floor and roof diaphragms have the strength and stiffness needed to collect and redistribute forces from the frames and walls as needed, and do not present a weak link in the overall seismic load-resisting or gravity systems.	New	ALL	Yes
	Cripple Walls: Cripple walls below first-floor-level shear walls are braced to the foundation with wood structural panels.	A.3.2.7.7	W1, W2	Yes
	Wood Sills: All wood sills are bolted to the foundation and sill bolts are spaced at 6 ft or less with acceptable edge and end distance provided for wood and concrete.	A.5.3.4	W1, W2	Yes

***Condition*[1]**	***Structural Evaluation Statement***	***Source*[2]**	***Model Building Type(s)***	***Relevant to One-Story?***
	Chimneys: No unreinforced masonry chimneys are present (RES1 Only).	A.7.9.1, A.7.9.2	W1	Yes
	Transfer to Steel Frames: Diaphragms are connected for transfer of seismic forces to the steel frames.	A.5.2.2	S1, S2, S3	Yes
	Steel Columns: The columns in seismic force-resisting frames are anchored to the building foundation.	A.5.3.1	S1, S4, S5	No
	Moment-Resisting Connections: All moment connections are able to develop the elastic moment (FyS) of the adjoining members.	A.3.1.3.4	S1	Yes
	Column Splices: All column splice details located in moment-resisting frames include connection of both flanges and the web.	A.3.1.3.6	S1, S4	No
	Chevron Bracing: Beams in chevron, or V-braced, bays are capable of resisting the vertical load resulting from the simultaneous yielding and buckling of the brace pairs.	A.3.3.2.3	S2	Yes
	Concentrically Braced Frame Joints: All the diagonal braces frame into the beam–column joints concentrically.	A.3.3.2.4	S2	Yes
	Connection Strength: All the brace connections develop the yield capacity of the diagonals.	A.3.3.1.5	S2	Yes
	K-Bracing: The bracing system does not include K-braced bays.	A.3.3.2.1	S2, S4	Yes
	Redundancy: The number of lines of braced frames in each principal direction is greater than or equal to 2.	A.3.3.1.1	S2	Yes
	Reinforcing Steel: The ratio of reinforcing steel area to gross concrete area is not less than 0.0012 in the vertical direction and 0.0020 in the horizontal direction.	A.3.2.2.2	RM1/RM2	Yes

Condition[1]	*Structural Evaluation Statement*	*Source*[2]	*Model Building Type(s)*	*Relevant to One-Story?*
	Transfer to Shear Walls and Steel Frames: Diaphragms are connected for transfer of seismic forces to the shear walls and steel frames.	A.5.2.1, A.5.2.2	S4	
	Transfer to Shear Walls: Diaphragms are connected for transfer of seismic forces to the shear walls.	A.5.2.1	C2, C3, PC1, RM1/RM2, URM	Yes
	Infill Wall Eccentricity: The centerline of the infill masonry wall is not offset from the centerline of the steel framing by more than 25% of the wall thickness.	A.3.2.6.5	S5	Yes
	Proportions: The height-to-thickness ratio of the unreinforced infill walls at each story is less than 9.	A.3.2.6.2	S5, C3	Yes
	Cavity Walls: The infill walls are not of cavity construction.	A.3.2.6.3	S5, C3	Yes
	Captive Columns: There are no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level.	A.3.1.4.5	C1, PC2	Yes
	Deflection Compatibility: Secondary components have the shear capacity to develop the flexural strength of the components.	A.3.1.6.2	C2	Yes
	Flat Slabs: Flat slabs or plates not part of the seismic force-resisting system have continuous bottom steel through the column joints.	A.3.1.6.3	C1, C2	No
	Wall Anchorage at Flexible Diaphragms: Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm.	A.5.1.1	C2, PC1, RM1/RM2	Yes
	Infill Wall Connections: Masonry is in full contact with frame.	A.3.2.6.1	C3	Yes

Condition[1]	***Structural Evaluation Statement***	***Source***[2]	***Model Building Type(s)***	***Relevant to One-Story?***
	Infill Walls: The infill walls are continuous to the soffits of the frame beams and to the columns to either side.	A.3.2.6.4	C3	Yes
	Wall Thickness: Thicknesses of bearing walls are not less than 1/40 the unsupported height or length, whichever is shorter, nor less than 4 in. (101 mm).	A.3.2.3.5	PC1	Yes
	Topping Slab: Precast concrete diaphragm elements are interconnected by a continuous reinforced concrete topping slab with a minimum thickness of 2 in. (51 mm).	A.4.5.1	PC1, PC2, RM1/RM2	Yes
	Wood Ledgers: The connection between the wall panels and the diaphragm does not induce cross-grain bending or tension in the wood ledgers.	A.5.1.2	PC1, RM1/RM2, URM	Yes
	Topping Slab to Walls or Frames: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements are doweled for transfer of forces into the shear wall or frame elements.	A.5.2.3	PC1, RM1/RM2	Yes
	Foundation Dowels: Wall reinforcement is doweled into the foundation.	A.5.3.5	RM1/RM2	Yes
	Girder-Column Connection: There is a positive connection using plates, connection hardware, or straps between the girder and the column support.	A.5.4.1	PC1, PC2, RM1/RM2	Yes
	Cross Ties in Flexible Diaphragms: There are continuous cross ties between diaphragm chords.	A.4.1.2	PC1, RM1/RM2	Yes
	Diagonally Sheathed and Unblocked Diaphragms: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft (12.2 m) and aspect ratios less than or equal to 4-to-1.	A.4.2.3	PC1, RM1/RM2, URM	Yes
	Corbel Bearing: If the frame girders bear on column corbels, the length of bearing is greater than 3 in. (76 mm).	A.5.4.3	PC2	Yes

Condition[1]	*Structural Evaluation Statement*	*Source*[2]	*Model Building Type(s)*	*Relevant to One-Story?*
	Straight Sheathing: All straight-sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered.	A.4.2.1	RM1/RM2, URM	Yes
	Beam, Girder, and Truss Supports: Beams, girders, and trusses supported by unreinforced masonry walls or pilasters have independent secondary columns for support of vertical loads.	A.5.4.5	URM	Yes
	Masonry Layup: Filled collar joints of multi-wythe masonry walls have negligible voids.	A.3.2.5.3	URM	Yes
	Proportions: The height-to-thickness ratio of the shear walls at each story is less than the following: Top story of multi-story building: 9; First story of multi-story building:15; All other conditions: 13	A.3.2.5.2	URM	
	Spans: All wood diaphragms with spans greater than 24 ft (7.3 m) consist of wood structural panels or diagonal sheathing.	A.4.2.2	URM	
	No other conditions are known to be present (not covered by the above) and may result in increased probability of the failure of the structural system and its ability to resist lateral forces or carry gravity loads.	New	ALL	Yes

[1] In the Condition column, enter one of the following four possible responses for each applicable evaluation statement: C for "Compliant," NC for "Noncompliant, U for "Unknown," or NA for "Not Applicable.

[2] Values that start with "A.2" in the Source column refer to section A.2 of ASCE 41-17 (ASCE, 2017). Statements marked "New" were developed by ImageCat to address the condition, connections, and horizontal diaphragms (roofs and floors).

3.4.2. STRUCTURAL DEFICIENCY SCORING

The response to the Structural Evaluation Statements of Table 4 can now be scored by assigning a value in the Score column of Table 5 for each category of compliance assigned for the structure condition in Table 4. The scoring system shown in Table 5 allows for Structural Engineering judgment when the responses are provided by a qualified evaluator, i.e., by either a Civil or Structural Professional Engineer, when evaluating deficiencies and their impact (i.e., judgements of “Limited Concern” or “High Concern.”

Table 5. Structural Deficiency Scoring

Response to Structural Evaluation Statement	*Score*
Compliant (C)	0.00
Noncompliant with Limited Concern (NCL)	1.00
Noncompliant with High Concern (NCH)	2.00
Unknown (U)	0.25
Not Applicable (NA)	0.00

After providing responses to each Structural Evaluation Statement listed for the building in Table 4 (basic Building Stability and selected statements for individual Model Building Types), the score for each response will be added to calculate a total score for both the pre-retrofit and post-retrofit conditions. Table 6 indicates the Collapse Performance Categories that will be assigned for the total scores within the ranges shown in the second column.

Table 6. Collapse Performance Categories

Collapse Performance Category	*Total Score from Responses to All Structural Evaluation Statements*
Baseline	0.0 – 1.5
Sub-Base	1.75 – 3.0
Ultra Sub-Base	> 3.0

3.5. Establishing Default Values of Fragility Medians for Nonstructural Damage States (NSA, NSD)

Table 7 presents the default values for nonstructural fragility to be applied to the pre-retrofit condition to estimate damage states and repair costs, and Table 8 provides the same data for the post-retrofit building condition. The values are a function of the UBC Seismic Zone and the year built and are used to set median thresholds for the Complete damage state for nonstructural elements. Table 7 presents the default values as acceleration (in “g” units) for nonstructural acceleration-sensitive (NSA) items, like building service equipment. Medians for other NSA damage states (i.e., Slight, Moderate, Extensive) are found by scaling as indicated in footnote 1 below Table 7. Table 9 presents the default values for nonstructural drift-sensitive (NSD) items, like building service equipment, as drift ratios for each damage state.

ImageCat assigned the default values for nonstructural fragility in Tables 7 and 8 to represent typical installations seen in older construction. Where extensive building renovations have replaced NSA elements (e.g., building service equipment) or NSD elements (e.g., nonstructural partitions, curtain wall, etc.), it may be more appropriate to use the year of the renovation to set the nonstructural fragility default values.

Table 7. Default Values for NSA Damage Fragility Medians (g) for Complete[1] Damage State for Pre-Retrofit Condition[2]

Uniform Building Code (UBC) Edition[3]	*UBC Seismic Zone 1*	*UBC Seismic Zone 2*	*UBC Seismic Zone 3*	*UBC Seismic Zone 4*
Pre-Code	0.5	0.5	0.5	0.5
1935-1946 Editions	0.5	0.6	0.75	—
1949-1967 Editions	0.5	0.75	1.0	—
1967-1973 Editions	0.5	0.75	1.0	—
1976, 1979 Editions	—	0.75	1	1.2
1982, 1985 Editions	—	0.75	1	1.2
1988-1994 Editions	—	0.9	1.1	1.5
1997 Edition or later (i.e., IBC)	—	1	1.25	1.8

[1] The Median for the "Extensive" Damage State is 75% of the “Complete” Damage State. "Moderate" Damage begins at 50% of “Extensive” Damage. "Slight" Damage begins at 50% of “Moderate” Damage.
[2] NSA medians are set relative to the "Complete" Damage State median. Defaults are modified per NSA formula and scores in Equation 1 in Section 3.6.3, accounting for the three NSA relevant statements.
[3] Use the year built to infer UBC or IBC edition used for original design. Major renovations that replaced building service equipment and other NSA elements would require upgrade.

Table 8. Default Values for NSA Damage Fragility Medians (g) by Complete[1] Damage State for Post-Retrofit Condition[2]

Building Code Edition[3]	*Default Value*
UBC 1997, Seismic Zone 2	1.0
UBC 1997, Seismic Zone 3	1.5
UBC 1997, Seismic Zone 4	2.0
ASCE 7; IBC Seismic Design Category B	1.25
ASCE 7; IBC Seismic Design Category C	1.75
ASCE 7; IBC Seismic Design Category D	2.25

[1] The Median for the "Extensive" Damage State is 75% of the “Complete” Damage State. "Moderate" Damage begins at 50% of “Extensive” Damage. "Slight" Damage begins at 50% of “Moderate” Damage.
[2] NSA medians are set relative to the "Complete" Damage State median. Defaults are modified per NSA formula and scores in Equation 1 in Section 3.6.3, accounting for the three NSA relevant statements.
[3] Use the year built to infer UBC or IBC edition used for original design. Major renovations that replaced building service equipment and other NSA elements would require upgrade.

Table 9. Default Values for Drift Ratios[1] for NSD Damage Fragility Medians by Damage State

Condition	*Slight Damage*	*Moderate Damage*	*Extensive Damage*	*Complete Damage*
Pre-Retrofit	0.004	0.008	0.015	0.03
Post-Retrofit	0.004	0.008	0.025	0.05

[1] Default values are modified per NSD scores and scaling formula from Equation 2 in Section 3.6.3, accounting for the five NSD relevant statements.

3.6. Adjusting for Nonstructural Deficiencies

Nonstructural scores are used for improved modeling for the life-safety, damage, and downtime impacts of nonstructural items. Some nonstructural items (nonstructural acceleration-sensitive elements, or NSA) are sensitive to accelerations to which they are subjected. These items are either sensitive to ground accelerations if the items are at or below grade or are sensitive to amplified in-structure accelerations if the items are above grade. Other nonstructural items (nonstructural drift-sensitive elements, or NSD) are sensitive to inter-story drifts to which they are subjected. Seismic deficiencies for nonstructural systems may have impacts on life-safety, damage, and/or downtime.

3.6.1. NONSTRUCTURAL EVALUATION STATEMENTS

ASCE 41-17 includes more than 100 Evaluation Statements in the nonstructural checklist (listed in Table 17-38 of ASCE 41-17 (ASCE, 2017)). Groups of evaluation statements are presented for:

- Life Safety Systems (e.g., fire safety, emergency power)
- Hazardous Materials

- Architectural Ceilings
- Light Fixtures
- Cladding, Glazing, and Masonry Veneer
- Parapets, Cornices, Ornamentation, and Appendages
- Stairs and Egress
- Contents and Furnishings
- Mechanical and Electrical Equipment
- Piping and Ducts
- Elevators

Because there are so many Evaluation Statements in ASCE 41-17 for nonstructural elements, ImageCat condensed them to a minimum efficient list of 10 evaluation statements to be used in the updated seismic structural module of the BCA Toolkit as shown in Table 10. The same evaluation statements should be completed for both the pre-retrofit and post-retrofit conditions of the building to be mitigated.

For each evaluation statement, responses will be used to modify parameters for modeling life-safety, nonstructural (NSA and NSD) damage, and downtime concerns, as appropriate. As indicated in the Condition column, each nonstructural statement should be evaluated once for the pre-retrofit condition and once for the post-retrofit condition. For each of these two conditions, a response should be given as: C for “Compliant,” NC for “Noncompliant, U for “Unknown,” or NA for “Not Applicable.”

3.6.2. NONSTRUCTURAL DEFICIENCY SCORING FOR LIFE-SAFETY

A scoring method will be used to determine the life-safety impact of nonstructural deficiencies based on the entries in the Life Safety column of Table 10. An “X” in the Life Safety column of Table 10 indicates whether damage to or failure of the system is likely to have life-safety consequences. As shown in Table 10, eight of the ten evaluation statements are relevant to life safety. A response of Noncompliant for these evaluation statements will contribute to the Nonstructural Life-Safety rating and may change the Collapse Factor. Nonstructural life-safety performance will be categorized as follows:

- Life-safety performance will be deemed to be “Good” if the responses to the eight relevant evaluation statements are “Compliant,” and none of the eight relevant evaluation statements has a response of “Unknown.”
- Life-safety performance will be deemed to be “Fair” when the response to one evaluation statement is “Noncompliant” or when there are multiple “Unknown” responses.
- Life-safety performance will be deemed to be “Poor” when the responses to multiple evaluation statements are “Noncompliant” or when the responses to all ten evaluation statements are “Unknown.”

Table 10. Nonstructural Evaluation Statements for Life Safety, Damage, and Downtime for Pre-Retrofit and Post-Retrofit Conditions[1]

Condition[2]	*Statement*	*Life Safety[3]*	*NSA Score[4]*	*NSD Score[4]*	*Downtime Scaling Factor*
	Life-safety systems (fire detection and suppression, emergency power, and lighting) are braced and anchored.	X	0,2,1,0		
	Hazardous, flammable, or explosive materials are not present or are securely contained in braced and anchored equipment, and piping with flexible couplings and shut-off valves.	X			
	No tall unreinforced brick masonry, hollow clay tile masonry, or other heavy unbraced partitions are present.	X		0,1,1,0	
	No asbestos is present that may be released by earthquake damage or must be mitigated for inspection or repairs.	X			2
	Above-ceiling items weighing more than 40 pounds are tethered or well-anchored and braced to the structure above to prevent falling hazards.	X	0,2,1,0		
	Heavy precast concrete exterior cladding or nonstructural panels are well anchored to structural frames or floors with detailing to accommodate building drifts and accelerations without damage or loss of support.	X		0,2,1,0	
	No heavy unreinforced masonry or stone veneers, masonry cornices or parapets, or unreinforced masonry chimneys are present.	X		0,1,1,0	
	All full-height architectural partitions are anchored to the floor below and laterally braced to floor above.			0,1,1,0	
	Exit stairways are not enclosed by unreinforced masonry walls, and stairs are securely attached to the supporting structure with detailing to accommodate expected drifts.	X		0,1,1,0	

Condition[2]	*Statement*	*Life Safety*[3]	*NSA Score*[4]	*NSD Score*[4]	*Downtime Scaling Factor*
	Equipment important to continued occupancy and function within the building (building service equipment) is well anchored and braced to resist earthquake forces and tolerate displacements.		0,2,1,0		1.5

[1] Reproduced from Table 17-38 of ASCE 41-17 (ASCE, 2017).
[2] Provide a response for each statement for both the pre-retrofit condition and post-retrofit condition. Indicate C for “Compliant,” NC for “Noncompliant, U for “Unknown,” or NA for “Not Applicable.
[3] An X indicates whether damage to or failure of the system is likely to have life-safety consequences.
[4] Assign a numerical score based on the response provided in the Condition column. Each of the four scores correspond to the four possible responses to the evaluation statements for C — “Compliant” condition, the second number for an NC — “Noncompliant” condition, the third number for a U — “Unknown” condition, and the fourth number for an NA — “Not Applicable” condition.

3.6.3. NONSTRUCTURAL DEFICIENCY SCORING FOR DAMAGE TO NONSTRUCTURAL ITEMS (NSA AND NSD)

A scoring method will be used to determine the damage impact of nonstructural deficiencies based on the entries in the NSA column of Table 10 for nonstructural acceleration-sensitive (NSA) components (equipment and contents) and the NSD column of Table 10 for nonstructural drift-sensitive (NSD) components (e.g., nonstructural partitions, curtain walls, etc.). For each evaluation statement, four possible scores are listed for either NSA or NSD, where each of the four scores correspond to the four possible responses to the evaluation statements: C = Compliant, NC = Noncompliant, U = Unknown, or NA = Not Applicable. For example, a set of scores listed as “0,2,1,0” indicates a score of 0 for a response of Compliant, a score of 2 for a response of Noncompliant, a score of 1 for a response of Unknown, and a score of 0 for a response of Not Applicable. Note that in each set of scores, if a response is either Compliant or Not Applicable, then the score will be 0. As shown in Table 10, eight of the ten evaluation statements could have NSA or NSD scores. After the scores are assigned in the NSA and NSD columns of Table 10, based on the responses to the evaluation statements in the first column, the sum of the scores in the NSA column and the sum of the scores in the NSD column are calculated. Then, the following formulas will be used to determine the appropriate scaling factors for the NSA Damage State medians and the NSD Damage State medians, respectively.

$$\textit{Scaling factor for NSA Damage State Medians} = (8 - \Sigma\ \textit{Total NSA Scores})\ /\ 8 \qquad (1)$$

Where:

Scaling factor for NSA Damage State Medians is the value that will be multiplied by the NSA default Damage State Median

Total NSA Score is the sum of all scores in the NSA column of Table 10

and

$$\textit{Scaling factor for NSD Damage State Medians} = (8 - \Sigma\ \textit{Total NSD Scores})\ /\ 8 \qquad (2)$$

Where:

Scaling factor for NSD Damage State Medians is the value that will be multiplied by the NSD default Damage State Median

Total NSD Score is the sum of all scores in the NSD column of Table 10

As shown in Equations 1 and 2 above, after the NSA or NSD scores are summed to obtain a total score, the total score is subtracted from 8. Then that net is divided by 8 to arrive at the scaling factor to be applied to the Complete Damage State medians described in Section 3.5. Multiplying the NSA

Complete Damage State median and NSD Complete Damage State median by the scaling factors will reduce the corresponding NSA and NSD default medians for nonstructural damage.

Table 11 shows examples of responses that could be given to each nonstructural evaluation statement in Table 10 that is relevant to NSA. Then, the score for each response would be used to calculate the scaling factor for the NSA Complete Damage Median. For example, for the first evaluation statement in Table 10, if life-safety systems are poorly anchored and, therefore, Noncompliant, the NSA score would be 2. For the fifth evaluation statement in Table 10, if above-ceiling items are present and found to be poorly secured, they would be considered Noncompliant, and the NSA score would be 2. For the last evaluation statement in Table 10, if other equipment is Compliant, the NSA score would be 0. Then, the total score for the NSA evaluation statements is 2 + 2 + 0 = 4. Using Equation 1, the scaling factor for the NSA Complete Damage State median would be calculated as (8 – 4) / 8 = 0.5.

Table 11. Hypothetical Example of Responses and Associated Scores for NSA Nonstructural Evaluation Statements

Nonstructural Evaluation Statement Applicable to NSA	*Response*	*NSA Score*
Life-safety systems (fire detection and suppression, emergency power, and lighting) are braced and anchored.	Noncompliant	2
Above-ceiling items weighing more than 40 pounds are tethered or well-anchored and braced to the structure above to prevent falling hazards.	Noncompliant	2
Equipment important to continued occupancy and function within the building (building service equipment) is well anchored and braced to resist earthquake forces and tolerate displacements.	Compliant	0
Total Score		4

The last column of Table 10 is used to obtain a scaling factor for downtime. For the fourth evaluation statement about asbestos in Table 10, if asbestos is present and may be released in significant quantities by earthquake damage, the downtime duration should be multiplied by 2.0 to account for special equipment, decontamination, and abatement, which would slow other repairs and delay re-occupancy. For the last evaluation statement about equipment in Table 10, if equipment that is important for continued occupancy and function of the building is anchored poorly and unbraced, the downtime duration should be multiplied by 1.5. The sum of the downtime scaling factors for these two statements should be limited to a maximum total of 2.0. Therefore, if both statements are true, then the maximum value of the sum of their downtime scaling factors should be 2.0 and the total downtime should be calculated by 2.0 times the normal duration.

As indicated in the footnotes of Tables 7 and 8, a default damage median for an NSA damage threshold will be calculated as a fixed percentage of the previous higher damage threshold. After calculating the median for the Complete damage state, the median for the Extensive damage state will be calculated as 75% of the median of the Complete damage state; the median for the Moderate damage state will be calculated as 50% of the median for the Extensive damage state; and the median for the Slight damage state will be calculated as 50% of the median of the Moderate damage state. After the default medians for the NSA damage thresholds are established, they will be multiplied by the NSA scaling factor calculated by Equation 1.

As shown in Table 9, the default medians for the NSD Complete damage state are predetermined, along with the respective fractional relationships for the Extensive, Moderate, and Slight damage thresholds. After the default medians for the NSD damage thresholds are established, they will be multiplied by the NSD scaling factors calculated by Equation 2.

4. Implementation Steps

4.1. Process for Completing a Benefit-Cost Analysis in the Updated BCA Toolkit

The process that will be used for completing a benefit-cost analysis using the updated seismic structural module of the BCA Toolkit is depicted in Figure 2. The figure shows what parts of the current process will be unchanged and what parts will be changed:

1. Current sections – The sections of the seismic structural module that do not need to be updated to implement the new seismic methodology.
2. Impacted sections – The sections of the module that will need to be updated to implement the new seismic methodology.
3. New sections – The new sections of the module that will be added to implement the new seismic methodology.

In the second section of Figure 2, the dashed lines indicate the process flow used in the current version (Version 6.0) of the BCA Toolkit. In all three sections of Figure 2, the solid lines represent the process flow that will be followed once the new seismic methodology is implemented.

The changes made to the BCA Toolkit will affect the Building Vulnerability Parameters shown in step 6 of Figure 2. The improved process will use the new seismic evaluation statements to select the default vulnerability parameters. Table 12 shows the modifications that will be made to the sections of the seismic structural module to implement the new methodology. After performing the benefit-cost analysis, the analyst should inspect the results and then perform subsequent iterations with revised HAZUS modeling or with revised cost or value information as needed.

4.2. Post-Retrofit Damageability

The process described in Sections 3.3 to 3.6 and summarized in Section 4.1 helps to characterize the pre-retrofit damageability of the structure and the high life-safety and economic consequences associated with the existing condition of the building, prior to mitigation actions. To evaluate the

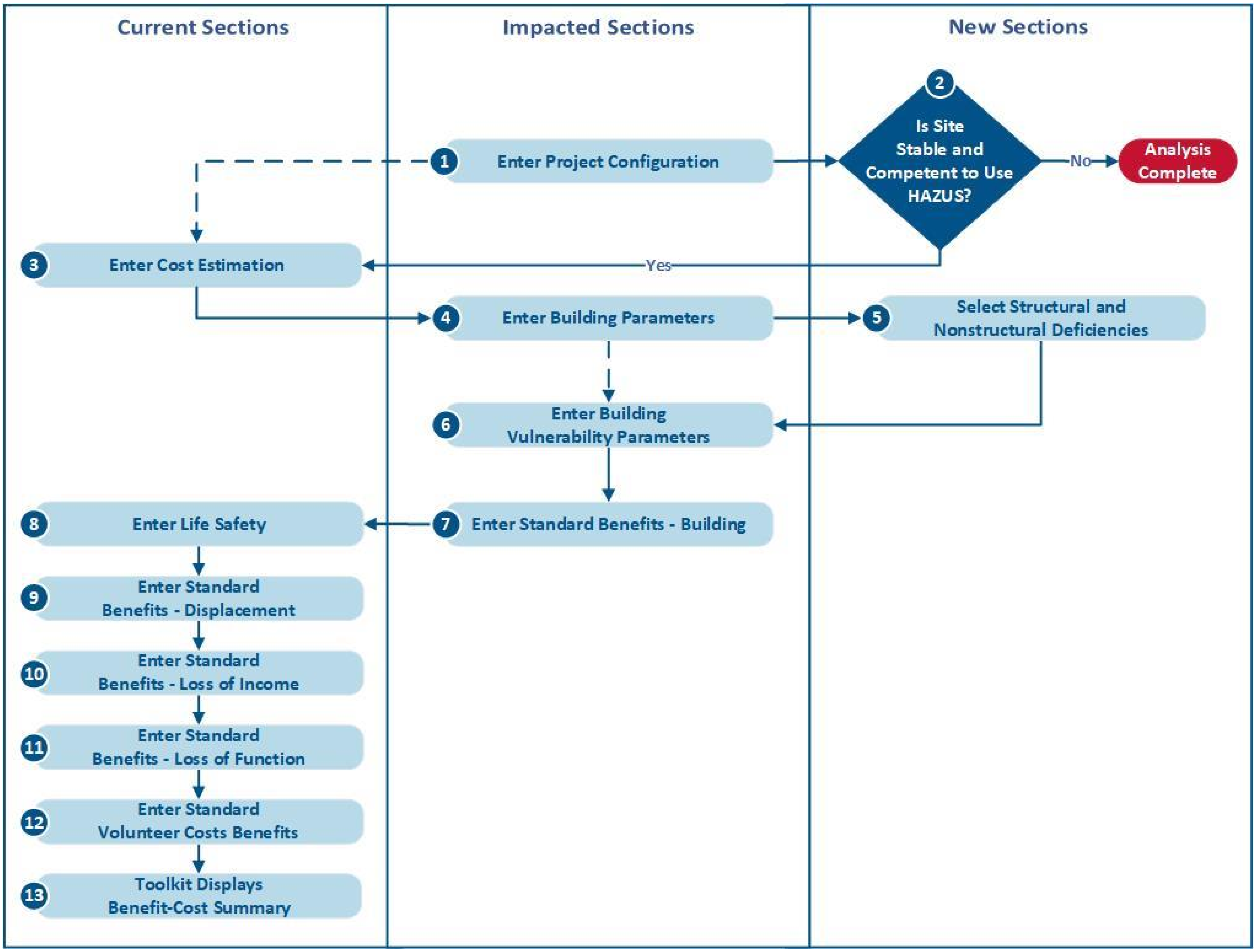

Figure 2. Benefit-Cost Analysis Process Flow for Seismic Mitigation Project

Table 12. Changes in the Process Used to Complete a Benefit-Cost Analysis for a Seismic Mitigation Project in the Updated BCA Toolkit

Step Number in Figure 2	*Section*	*Section Fields*
2	Site Stability	▪ Confirm site stability: ○ The user is asked to establish whether ground shaking is the dominant seismic hazard and that the building will not be subject to high levels of damage from soil liquefaction, earthquake-induced landslide, or surface fault rupture hazards. ○ The user will select Yes or No.
2	HAZUS Eligibility	▪ Confirm that HAZUS is capable of performing the analysis and will be able to accurately represent the response and risks associated with the building, both pre- and post-retrofit: ○ The user is asked to establish whether the HAZUS software is competent to model building seismic impacts, including damage and life-safety. ○ The user will select Yes or No.
4	Building Parameters	▪ Existing Fields: ○ Latitude: Read-only, pre-populated ○ Longitude: Read-only, pre-populated ○ Site Class: User-selected ○ Building Use: User-selected ▪ New fields added, which were moved from the Building Vulnerability Parameters Section ○ Use Default Building Parameter: User-selected ○ Model Building Type: User-selected, before and after mitigation ○ Design Level: User-selected, before and after mitigation ○ Number of Stories in the Building: User-entered, before mitigation only ○ Height in Feet (Base on Stories): Pre-populated ▪ New Fields to be Added: ○ Year Property was Built: User-entered ○ With the Year Property was Built, location Site Class, and Model Building Type, *Cs* and *Te* will be set for the pre-retrofit condition.
5	Structural Evaluation Statements	▪ Complete the Structural Evaluation Statements. ○ The user will be required to supply responses for both the pre-retrofit and post-retrofit conditions.

Step Number in Figure 2	*Section*	*Section Fields*
		○ These responses will be used to assign a Collapse Performance Category and assign HAZUS structural modeling parameters. ▪ Retrofits should be designed to mitigate some or all the identified deficiencies, and retrofits may include strengthening and stiffening measures that also need to be specified (e.g., by user over-ride as described below). ○ A set of structural evaluation statements will be presented, adapted from ASCE 41-17, for the user to identify serious seismic deficiencies present in the building structure (both pre- and post-mitigation). Then, the Collapse Performance Category (i.e., Baseline, Sub-Base or Ultra Sub-base) will be assigned. ○ With the above information and the Collapse Performance Category, other parameters will be set (i.e., Alpha1, Alpha2, Alpha3, Gamma, Lambda, Mu, Elastic Damping, Kappa). ○ The user will indicate other Structural Enhancements with Retrofit. Otherwise, assume retrofits restore Baseline performance, with Cs = 75% of that required by the 1997 UBC. ○ Toolkit will display: Collapse Performance Category (i.e., Baseline, Sub-Base or Ultra Sub-Base)
5	Nonstructural Evaluation Statements	▪ Complete the Nonstructural Evaluation Statements. ○ The user will be required to provide responses for both the pre- and post-retrofit conditions. ○ The responses will be used to assign HAZUS appropriate nonstructural parameters for life-safety, damage, and downtime. ▪ A set of nonstructural evaluation statements will be presented, adapted from ASCE 41-17, for the user to identify serious seismic deficiencies present in architectural elements, building service equipment and safety systems, and other nonstructural elements affecting building safety as well as the damageability of these components, both pre- and post-mitigation. ▪ The user will indicate other Non-structural Enhancements with Retrofit. ▪ The Toolkit will display: Nonstructural Life-Safety Category and the resulting scaling factors to apply to NSA and NSD damage threshold medians
6	Building Vulnerability Parameters	▪ After completing the Building Parameters-Seismic section, the Structural Evaluation Statements section, and the Nonstructural Evaluation Statements section, the Toolkit will look up default vulnerability parameters and will display them to the user. The user will have the option to override the default values.

Step Number in Figure 2	***Section***	***Section Fields***
		▪ Previous Fields ○ Use Default Building Parameter: User-selected ○ Model Building Type: User-selected, before and after mitigation ○ Design Level: User-selected, before and after mitigation ○ Number of Stories in the Building: User-entered, before mitigation only ▪ Existing Fields: ○ Use Default Vulnerability Parameters: User-selected ○ Elastic Period (Te): Pre-populated, before and after mitigation ○ Lateral Force Coefficient (Cs): Pre-populated, before and after mitigation ○ Elastic Damping: User-selected, before and after mitigation ○ Degradation Factor: Pre-populated, before and after mitigation ○ Complete Structure Damage (STR): Pre-populated, before and after mitigation ○ Complete Non-Structural Damage (NSD): Pre-populated, before and after mitigation ○ Complete Structure Damage (NSA): Pre-populated, before and after mitigation ○ Location of Acceleration-sensitive Components: User-selected, before and after mitigation ▪ The user will continue to have the capability of modifying the "NSD Details" and "NSA Details." ○ The NSD Details will comprise Component Name, %, As-Is Drift Ratio and SD Complete, As-Retrofit Drift Ratio and SD Complete. ○ The NSA Details will comprise Component Name, %, Location, As-Is Anchorage Type and SA Complete, As-Retrofit Anchorage Type and SA Complete. (Anchorage Types: No Anchorage, Anchored/Braced, Spring Mounted, or Snubbed).

benefits of seismic retrofits, the reduced vulnerability of the projected post-retrofit condition must also be modeled. Reductions in the number and severity of casualties and injuries and reductions in damage and downtime may then be translated to economic terms to obtain an estimate of the expected present-value benefit of retrofit, which can then be compared to the estimated cost of retrofit.

In general, seismic retrofits seek to mitigate as many of the identified serious seismic deficiencies that are practical and cost-effective. Such improvements will be readily accommodated in the updated BCA Toolkit. Where there are responses of “Noncompliant” to the Evaluation Statements for the pre-retrofit condition, there could be responses of “Compliant” for the post-retrofit condition, indicating that the retrofit will “cure” the corresponding deficiencies. For the building structure, the structural retrofit may result in improving the Collapse Performance Category from Ultra Sub-base to either Sub-base or Baseline structural performance. Nonstructural retrofits could result in similar improvements.

In addition to mitigating specific structural deficiencies as captured by the ASCE 41 Evaluation Statements, seismic retrofits may provide additional strength and stiffness to the structure. Such retrofits can be accounted for by user modification of the post-retrofit lateral force coefficient, *Cs*, and the building fundamental period, *Te*. The Structural Engineer who provides the evaluation of the existing building and proposes retrofit schemes and associated costs may provide suitable values for *Cs* and *Te*. These values will vary with the performance objectives selected by the subapplicant.

Few buildings can be brought up to “current code” by seismic retrofit, so that effectively represents a limiting case, which would be useful for assessing the maximum benefit that a retrofit could produce for a given building.

4.3. Capacity Spectrum Solution Enhancement

In addition to improving and simplifying the selection of the default building vulnerability parameters, the BCA Toolkit will also be updated to address the issues outlined in the section of the Earthquake Structural Full Data Module methodology report (FEMA, 2008) on the Need for an Empirical Solution. An empirical Capacity Spectrum solution was needed in 2008 to address errors found in the HAZUS solution that existed at that time. The Calculations in the BCA Toolkit will be updated to replacing the previous empirical solution by using calculations adapted from the Risk Calculation Tool (RCT) (Kircher, 2010), which correctly implements the Capacity Spectrum solution for determining the *Sd* and *Sa* values. Since the updated calculations will directly implement HAZUS theory, the accuracy of the calculations will be improved. The updated calculation method may or may not increase calculated benefits.

5. Results of BCAs for Example Retrofits Projects

Benefit-cost analyses were completed for ten example seismic retrofit projects using two previous versions of the BCA Toolkit as well as the proposed updated seismic structural module. Then, the results of the three analyses, i.e., the BCRs, for each of the ten examples were compared. Descriptions of the ten example retrofit projects that were analyzed are listed in Table 13. Each of the ten example retrofit projects were analyzed, assuming they were being implemented at each of the following six site locations in FEMA Region IX: (1) San Francisco, CA, (2) Los Angeles, CA, (3) San Diego, CA, (4) Sacramento, CA, (5) Reno, NV, and (6) Hilo, Hawaii.

During 2012 and 2013, Ideation and ImageCat conducted the first analysis of the ten example retrofit projects using BCA Toolkit Version 4.5.5 (a predecessor of BCA Toolkit Version 6) using custom HAZUS parameters to better represent the damageability of the buildings pre- and post-

Table 13. Seismic Retrofit Projects Analyzed by the BCA Toolkit

Example Retrofit Number	*Model Building Type*	*No. Stories*	*Building Description*	*Description of Deficiency*	*Description of Retrofit*
1	W1	1	USGS Office at CalTech	Soft weak story condition caused by unanchored weak cripple walls	Bolt cripple wall sills to concrete foundation, add plywood to interior face of cripples at perimeter and add shear walls beneath main interior walls. Strap gravity posts to pedestals and main beams.
2	W1	3	College Dorm	Gypsum wallboard and stucco used as sheathing to resist seismic forces -- no plywood sheathing for shear walls, no hold-downs or straps	Strip stucco from exterior over contiguous vertical strips, install plywood panels, double sill plate, increase sill bolting, add hold-downs
3	W1	3	College Dorm	Soft, weak open front wood-frame building due to tuck-under parking at the first level. Gypsum wallboard and stucco used as sheathing to resist seismic forces -- no plywood sheathing for shear walls, no hold-downs or straps	Add 10 steel moment-frames, including foundation work and developing the forces back into the floor 2 diaphragms.
4	RM, PC1	1	City Warehouse	No direct steel roof-to-wall anchorage (uses wood ledger); diaphragm cross-ties are missing	Roof-to-wall anchorage and diaphragm cross-ties are added. This typical tilt-up retrofit also applies to masonry warehouses with wood roofs.
5	C1, C2	10	Urban City Hall	Nonductile concrete frame (C1)	Reinforced concrete or masonry shear walls (MBT changed to C2) added to reduce drifts and prevent nonductile failures in frames or connections. Retrofit lower stories and discontinue at some point where frame strength is adequate. Some columns could be fiber wrapped.

Example Retrofit Number	***Model Building Type***	***No. Stories***	***Building Description***	***Description of Deficiency***	***Description of Retrofit***
6	PC2	3	Parking Structure	Nonductile concrete -- precast frames as "Conrad Tables" with nonductile (shear critical) columns	Fiber wrap columns, add collectors, etc.
7	C1	6	Major State Agency Office Building	Perimeter moment frame with flat slab at interior, with slab punching shear weakness around columns. Heavy precast concrete panels at exterior - inadequate drift allowance. Heavy equipment above ceiling unsecured.	Retrofits add collars around slab/column joints at interior, tether exterior panels and secure above-ceiling items
8	C2	12	Principle Office of a Major Power and Water Utility	Nonductile concrete shear walls - lack boundary elements at ends of transverse walls at ends -- toe crushing results	Jacket ends of walls with fiber jackets for lowest three stories
9	S2	3	Library or University Office Building or Hospital MOB	Concentric braced steel frames; floors of metal deck with concrete fill. Thin-walled steel tube braces subject to local buckling; weak connections; lacks collectors.	Replace thin-walled tube steel braces with thicker sections and reinforce connections; add collectors
10	URM	3	Historic Mixed-Use Building in Pioneer Square, Seattle	Historic building 66 ft X 100 ft, 3 stories, timber piles. Unreinforced masonry bearing walls poorly anchored to wood floors with straight sheathing. Hollow clay tile partitions. Open front, story 1.	Bolt URM walls to floors and roof; develop anchors into diaphragm. Add braced frames at story 1 where soft-story is found. URM partitions removed (hollow clay tile) replaced with gypsum board on frame with plywood.

retrofit (FEMA, 2012). This analysis showed what BCRs could be produced with the existing BCA Toolkit by users who are HAZUS experts. In 2022 a second analysis was conducted of the ten example retrofits using BCA Toolkit Version 6 using default parameters. This analysis showed what BCRs could be produced with the latest version of the BCA Toolkit (Version 6) by users who did not seek assistance from HAZUS experts. Finally, a third analysis was conducted of the ten retrofits during 2023 by using the updated methodology that employed HAZUS-OSHPD with ASCE 41-17 Evaluation Statements, by using the improvements described in Section 3 of this report, and by following the process described in Section 4.1 of this report. The results of this analysis showed the greatly improved BCRs that could be produced using the proposed seismic structural module updates by users who did not need assistance from HAZUS experts. Similar to the process for completing BCAs in the other modules of the BCA Toolkit, professional engineers can now be used to provide input for the seismic structural module.

The ten bar graphs in Figures 3 and 4 show the BCRs produced (vertical axis) from analyzing each of the ten example retrofits (vertical axis) at each of the six site locations (horizontal axis). On each graph, a dashed line indicates where the retrofit would be considered to be cost effective, i.e., where the BCR is equal to 1.0. The results from using BCA Toolkit Version 6 run with default parameters show that only a few of the site locations for three of the ten retrofits (i.e., Retrofits #1, #4, and #6) had BCRs greater than 1.0 (for a total of 9 of the 60 analyses). The results from using BCA Toolkit Version 4.5.5 to complete a customized expert analysis shows higher BCRs than those produced by Version 6.0, with the majority of the site locations for all ten of the retrofits having BCRs greater than 1.0 (for a total of 29 of the 60 analyses). The results from using the updated seismic methodology also show that the majority of the sites for all ten of the retrofits had BCRs greater than 1.0 (for a total of 40 of the 60 analyses), and those BCRs were even higher than the BCRs produced using the customized expert analysis in Version 4.5.5.

6. Options When HAZUS-OSHPD BCA Fails

There may be cases when HAZUS-OSHPD cannot be used to perform an analysis, or an analysis may not be able to be completed because a site is suspected to be unstable. There also may be cases when the BCR produced by the BCA Toolkit is less than 1.0, indicating that the mitigation action would not be cost effective.

6.1. What to Do if the BCR is Less Than 1.0

If a BCA performed using default parameters results in a BCR that is less than 1.0, then the following revisions could be performed to improve the accuracy or modify the project to decrease costs and increase benefits:

1. The Structural Engineer and/or the expert in the HAZUS-OSHPD earthquake damage model could review parameters to see if any of them can be refined or improved. Subapplicant staff could review the building replacement value and occupant loads to ensure these values have been appropriately considered. If a retrofit project would result in benefits to the wider community, those added benefits could be considered.

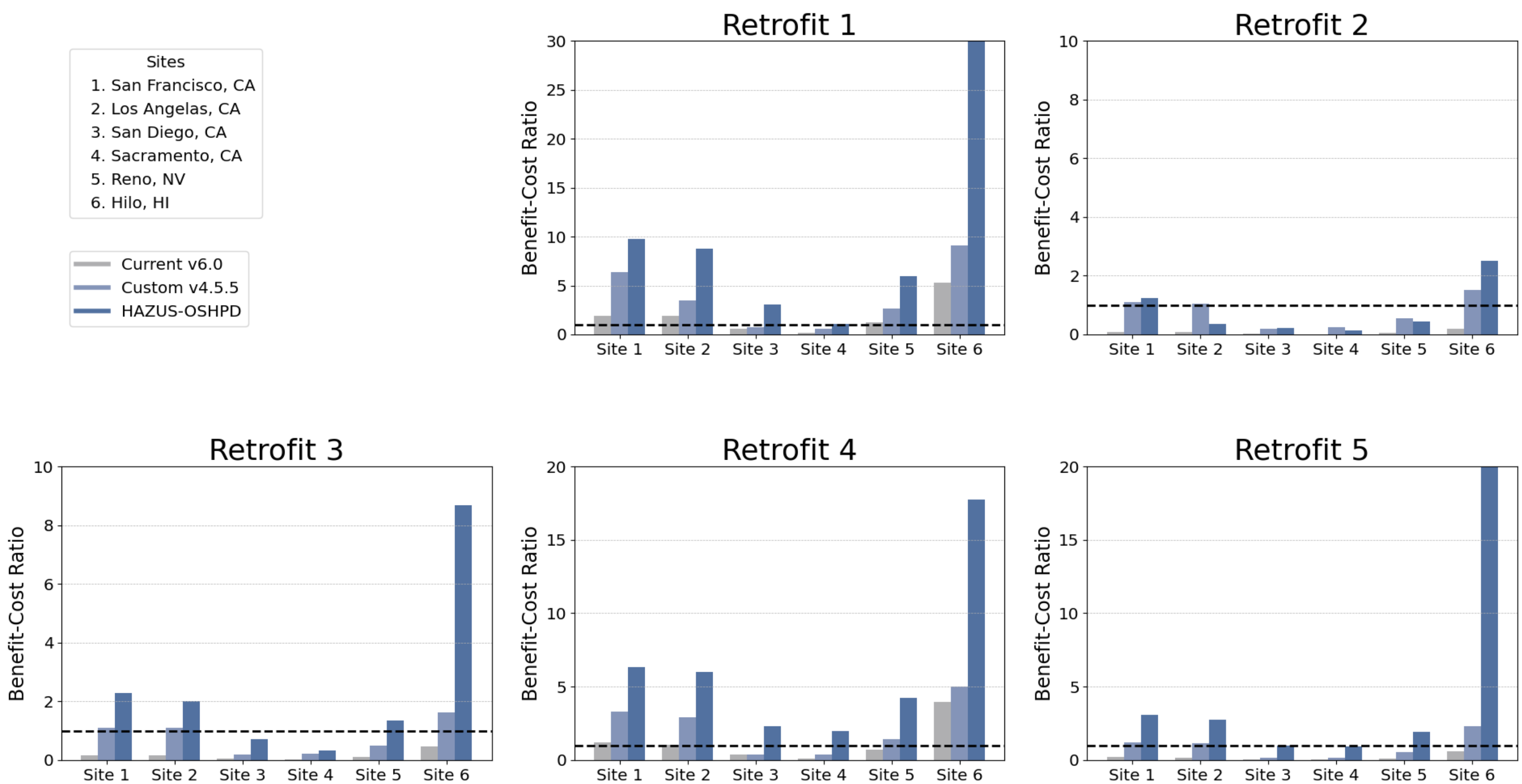

Figure 3. Comparison of BCRs Produced Using Versions of the BCA Toolkit to Analyze Retrofits #1 – #5 for V. 6.0, BCA Toolkit V. 4.5.5, and the Proposed Updated Methodology

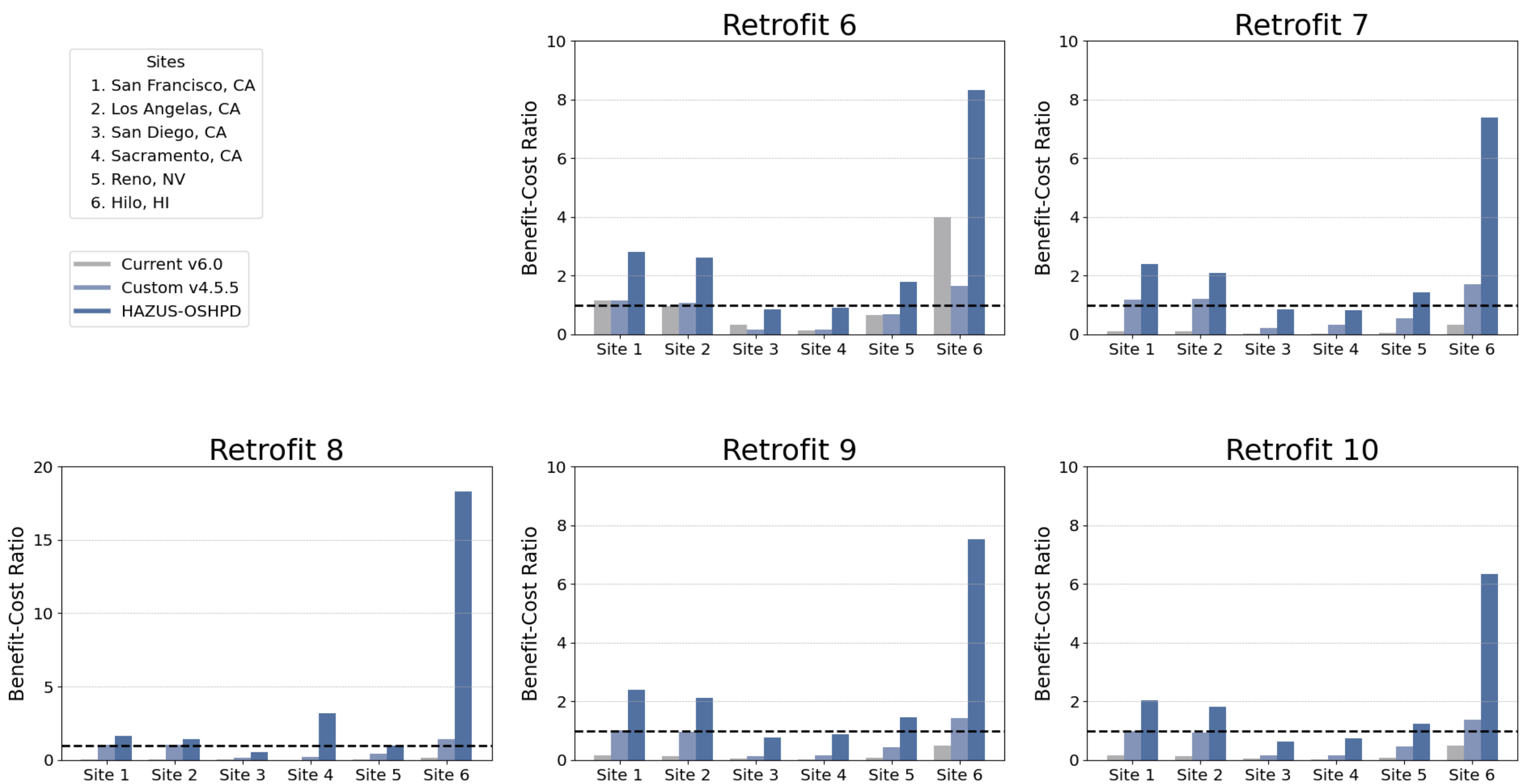

Figure 4. Comparison of BCRs Produced Using Versions of the BCA Toolkit to Analyze Retrofits #6 – #10

2. The retrofit design team could consider less-costly retrofit alternatives. The present value of the benefits of a retrofit would provide an upper bound estimate for the costs that could be justified for a cost-effective retrofit. Facility improvements that are not strictly related to the seismic retrofit could be excluded from the estimated retrofit costs and could be paid for by the subapplicant, so that such unrelated costs would not reduce the retrofit BCR.
3. Nonstructural retrofits could be included because these generally cost less than structural retrofits, but they can offer substantial benefits in damage reduction, preservation of function, and improvement in life-safety. In this way, the cost-effectiveness of the project with both structural and nonstructural retrofits combined could be improved.

Making these types of changes could result in increasing the BCR.

6.2. What to Do if HAZUS is Not Competent to Perform an Analysis

In some cases, HAZUS may not be competent to analyze a particular building. This could be the case when a building does not have a corresponding Model Building Type in HAZUS (e.g., it is an eccentric-braced frame structure rather than a concentrically braced frame) or when the seismic retrofit scheme is unconventional (e.g., base-isolation).

In some cases, an approximate analysis can be performed using the most similar Model Building Type in HAZUS. In other cases, an expert HAZUS modeler may be able to override default values and input appropriate capacity, fragility, and other inputs to represent the building's seismic performance pre- and post-retrofit.

If these are not options, then it may be necessary to use the first principles in conducting a benefit-cost analysis. This option is available in the BCA Toolkit as "Modeled Damages/Historical Damages/Professional Expected Damages." General engineering analysis (e.g., ASCE 41 Tier 2 or Tier 3) can be used to evaluate a building for multiple hazard levels (or "bins") that span the potential future of seismic shaking and can compute responses and associated consequences (i.e., "death, damage, and downtime") at those levels, both pre- and post-retrofit. The hazard-recurrence information for the site can be obtained, and the annual frequencies of occurrence can be found for the bounded ranges ("bins") of each hazard level. By integrating the consequences weighted by the bin frequencies of occurrence per year, the long-term average annual consequences can be obtained for each case, both pre- and post-retrofit. The reduction in annual consequences can then be taken as future annual benefits, extending over the remaining useful life of the building. FEMA values for casualties, fatalities, and other costs can be applied to monetize the consequences, and time-value-of-money principles can be used to bring the annual series of future benefits, in dollars, back to a present value. Then this value would be normalized by the present value estimated cost of the retrofit to obtain the BCR.

6.3. What to Do if a Site is Suspected to be Unstable

If a site is suspected to be unstable due to a high potential for soil liquefaction or earthquake-induced landslide, or if a site is found to be within a defined zone for surface fault rupture (e.g., California Earthquake Fault Rupture Zones), a geotechnical investigation is recommended to be performed. The investigation should examine the geologic conditions and existing foundation design to determine if future earthquake events may cause collapse, unacceptable damage, or loss of function from such hazards. If such serious consequences are expected to occur from future earthquakes, the Geotechnical Engineer may be able to recommend foundation modifications that would reduce or eliminate these impacts. Then, a more extensive BCA can be conducted to (a) consider the foundation-related damage and retrofit costs and then (b) combine those costs with the structural and nonstructural effects of shaking and the retrofit measures for the structure above the foundations. If such serious consequences are not expected to occur from future earthquakes, then the BCA may be conducted for the proposed retrofit without further consideration of site instability.

7. Additional Work for Certain Model Building Types

After the initial rollout of the improved seismic structural module of the BCA Toolkit, additional efforts may need to be considered for certain cases or Model Building Types (MBTs). The extent of such efforts may depend upon feedback from users or suggestions from other HAZUS and BCA experts.

7.1. Weak-Story Cases Needing Further Modification of *Cs*

For the following building types, *Cs* may need to be further modified:

- Multi-story apartment buildings with soft, weak, or open front (SWOF) and older dwellings (W1, W2) over crawl space with cripple walls. These buildings experience a combination of concentrated drift demand and weak story, so that standard code or pre-code strength values (*Cs*) may be too high, resulting in underestimating the damage and collapse potential.
- Precast Concrete Tilt-up warehouses. Older buildings of this type often have weak roof-to-wall connections and/or poor roof diaphragm tension cross ties. Analysis of the pre-retrofit condition using standard code or pre-code strength values (*Cs*) may underestimate the damage and collapse potential.
- Unreinforced Masonry (URM). These buildings all predate seismic building codes and may have multiple global and local collapse mechanisms. Unless they are historic, damaged buildings of this type may be demolished rather than repaired, changing the economics of a decision between retrofit and replacement.

7.2. Adding Model Building Types Not Currently in HAZUS

Some recent structural systems are not represented by the Model Building Types (MBTs) currently addressed in HAZUS. New MBTs, such as Buckling-restrained Braced Frames, Eccentric Braced Frames, and Cold-formed Steel Light-Framed Walls, could be developed for inclusion in the updated seismic module of the BCA Toolkit.

7.3. Post-Retrofit Damageability Modeling

There is no “standard” retrofit for all building types, and it is challenging to properly characterize the post-retrofit damageability of any building (see Section 4.2). ASCE 41 (ASCE, 2017) presents a number of performance objectives and prescribes ways to achieve the desired objectives. For example, it describes "Basic Performance Objective for Existing Buildings (BPOE)," "Enhanced Performance Objectives," and "Limited Performance Objectives."

In the future, FEMA may wish to implement an option in the BCA Toolkit in which users may select a specific performance objective per ASCE 41. The performance objective could then be used to assign HAZUS parameters that better capture the expected post-retrofit performance.

ASCE 41 provides “Deficiency-Based Evaluation and Retrofit Procedures” (ASCE 41 Section 3.4.3) and “Systematic Evaluation and Retrofit Procedures” (ASCE 41 Section 3.4.4). User scoring of Evaluation Statements with retrofit mitigations may improve collapse performance, e.g., from Ultra Sub-Base to either Sub-base or Baseline, similar to approaches using the “Deficiency-Based Evaluation and Retrofit Procedures.”

Retrofit to address specific deficiencies may not provide for overall strengthening of the lateral force-resisting system. Nevertheless, many seismic strengthening projects target weak lateral force-resisting systems. In the absence of more specific information, the new BCA Toolkit will assign a post-retrofit value of *Cs* as 75% of the UBC 1997 code, resulting in near-Benchmark seismic performance (see ASCE 41 Section 3.3 for Benchmark Buildings). The Structural Engineer who assists the sub-applicant should be aware of this and should adjust the *Cs* value if needed to better capture the expected post-retrofit performance.

Any original design enhancements beyond basic code should be considered. The *Cs* factors, periods, and other parameters used to model the pre-retrofit condition assume that the buildings were designed for code-minimum forces as ordinary buildings. The Importance Factor, I, was introduced in the 1976 UBC to require higher design forces for critical facilities, such as fire and police stations, emergency operations centers, and hospitals. The “I Factor” was 1.5 or 1.25, which increased design forces by 50% or 25%, respectively. For buildings originally designed using the 1976 UBC or later, it would be more accurate to consider such original design enhancements and modify the pre-retrofit *Cs* to suit.

7.4. Beta Testing and Other Steps Toward Implementation

After FEMA reviews the proposed methodology for implementing an improved seismic structural module in the BCA Toolkit as described in this report, the next step will be to perform Beta testing so that other HAZUS experts can review and validate the methods and assumptions described in Sections 3, 4, and 5 of this report. Specifically, the next step should be to verify the values used and consider further adjustments and improvements.

After the values, assumptions, and methods have been confirmed through Beta testing, further revisions of the seismic structural module of the BCA Toolkit and its associated documentation should be considered in response to any resulting comments and suggestions. This should entail:

- Incorporating any needed revisions or corrections and publishing final documentation, such as an updated methodology report, BCA Toolkit release notes, and BCA Toolkit help content.
- Reviewing BCA training materials and making recommendations for revisions so that they are compatible with the updated methodology and updated seismic structural module of the BCA Toolkit.

After the above testing and revision tasks have been completed, then the updated seismic structural module of the BCA Toolkit should be deployed for use.

7.5. Future Extensions

Future studies could be conducted to consider structures and challenges that are not included in the proposed updated seismic structural module described in this report. Such future studies could include:

- Special considerations for historic buildings, such as the benefits of historic preservation, added costs of repair consistent with historic fabric, etc.
- Non-building structures
- Previously retrofitted buildings
- Hospitals
- Public schools
- Asbestos-containing materials present
- Retrofits with Base Isolation or Supplemental Damping
- Essential Facilities (Police Station, Fire Stations, and Emergency Operations Centers)
- Unstable Sites (due to Liquefaction, Landslide, or Surface Fault Rupture)
- Tsunami Protection
- Utilities (water, sewer, natural gas, electric power, and internet service provider)

FEMA could decide to study or model the above items with the intention of incorporating them as improvements in future releases of the BCA Toolkit.

8. Additional Helpful Resources

In addition to the references cited in the body of this report, the following list of resources may be helpful for engineers and practitioners who are seeking more detailed information about HAZUS, performing a BCA for a seismic structural retrofit project, and accepted retrofit projects:

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APPENDIX A: Updated HAZUS *Te* and *Cs* Values

A.1 Overview of Seismic Design Codes

Seismic retrofit is used to strengthen existing buildings and/or to remedy serious seismic deficiencies in the earthquake-resisting system of a building. Typically, the deficient building is older, and it may have been designed for lower seismic forces or it may have used design codes, procedures, materials, or workmanship that have been revised over the years to provide better performance in resisting earthquakes. The strength and other structural properties of each building to resist earthquakes is, therefore, strongly a function of where and when it was first designed and constructed.

The design and construction of some buildings predate the first seismic design codes. These buildings may use a prohibited structural system (e.g., unreinforced masonry walls); they may lack a complete load path; they may have lower lateral force resistance; and they typically lack the positive seismic design features required by building codes. These buildings are referred to herein as “pre-code” structures.

The first seismic design code in the United States was the Uniform Building Code (UBC), published by the International Council of Building Officials (ICBO) in Whittier, California. The years that different editions were published, from 1927 to 1997, and the advancement contained in each edition are listed in Table A-1. After 1997, the UBC was replaced by the International Building Code (IBC) from the International Code Council (ICC). Over the span of time covered by the UBC, many earthquakes occurred, design procedures evolved (including dynamic analysis), and new building structural systems were developed. The UBC was changed to incorporate lessons learned from each large damaging earthquake and from the research and development that continued to occur. The earthquake ground shaking hazard varies throughout the U.S., depending on the size and activity of earthquake faults, as well as other geological conditions. Seismic zone maps were developed to provide stronger and tougher earthquake systems in proportion to the strength of future ground shaking expected. Starting in 1935, the UBC included a map to adapt seismic design force levels to the intensity of shaking expected in the region.

Table A-1. Uniform Building Code Milestones

Year of Publication	*Milestone*
1927	The first edition of the Uniform Building Code was published, and the first seismic design provisions are found in the appendix. The provisions were non-mandatory. The lateral earthquake forces were used for allowable stress design.
1935	Seismic Zones 1, 2 and 3 were introduced in the first Seismic Zone map, which covered 11 western states. The map followed many state and county boundaries. The provisions were mandatory where adopted.

Year of Publication	***Milestone***
1949	The Seismic Zones map was expanded to the 48 states in the continental U.S. The State of South Carolina was Zone 3, but it was otherwise like the subsequent map published in the next edition.
1952	Seismic Zones 0-3 were revised from the 1949 edition (South Carolina was revised to be Zone 2). The map stays the same (boundaries have straight lines). The Z-factor was introduced in the base shear equation. The seismic zones did not change from 1952 through the 1967 version.
1970	The Seismic Zones map was revised in general. The Wasatch front Zone was increased, and the Oregon zone was reduced.
1973	The Seismic Zones map was revised for the States of California and Nevada.
1976	The Seismic Zones map was revised in general. Zone 4 was introduced within California and Nevada.
1982	The Seismic Zones map was revised for Idaho and Montana.
1988	The Seismic Zones map was revised in general from United States Geological Survey (USGS) probabilistic maps. Zones 2a and 2b were introduced.
1994	The Seismic Zones map was revised for California and Oregon. (San Diego was Zone 4, and coastal Oregon was Zone 3).
1997	The Seismic Zones map was revised for Hawaii (made Zone 4). The base shear formula adopted strength-based design rather than allowable stress design.
2000 and beyond	The UBC was discontinued and was replaced by the International Building Code (IBC). The IBC is updated every three years.

In this appendix, the design lateral force coefficient (*Cs*) and structural period (*Te*) were compiled for the relevant structural model building types, as drawn from the UBC, for the two highest seismic zones. It is unlikely that more recent buildings designed under the IBC need seismic retrofit at present, although codes continue to change. Also, the design lateral force coefficient (*Cs*) values that are appropriate to use for pre-code structures are tabulated.

A.2 Evolution of the Seismic Force Equation

The lateral force coefficient, *Cs*, used in HAZUS is in strength design units (not allowable stress units), and it is derived from seismic design in building codes. *Cs* is a critical input in designing the lateral strength of the system and its members and connections. *Cs* is calculated by the following equation:

$$Cs = V/W \qquad \text{(A-1)}$$

where:

V is the total lateral force applied

W is the seismic weight of the building (see ASCE 7 (ASCE, 2022) and the relevant edition of the UBC).

From 1927 to 1994, seismic design forces were computed by the equations outlined in Table A-2, with force *V* used in allowable stress design procedures. In 1997, the UBC adopted strength design. The allowable stress design forces are converted to strength design by using the following equation:

$$Cs = 1.4 \times V/W \quad \text{(A-2)}$$

The design forces from the 1997 UBC do not require conversion.

Table A-2. Evolution of the Seismic Force Equation

Year(s)	*Equations Used for Calculating Seismic Force, V*
1927	$V = 0.075W$ (A-3) where: $W = D + L$ for soils with bearing pressure ≥ 2000 psf (Site Class B, C) where: W = seismic weight D = Dead Load L = Live Load $V = 0.10W$ (A-4) where: $W = D + L$ for soils with bearing pressure < 2000 psf (Site Class D, E) There was no adjustment for building height or period of vibration.
1935–1946	$V = CW$ (A-5) where: C is a constant defined below $W = D + 0.5L$ (Allowable Strength Design (ASD)) There was no adjustment for building height. For ZONE 1: C = 0.02 for bearing pressure ≥ 2000 psf (B, C) C = 0.04 for bearing pressure < 2000 psf (D, E) For ZONE 2: C = 0.04 for bearing pressure ≥ 2000 psf (B, C) C = 0.08 for bearing pressure < 2000 psf (D, E)

Year(s)	*Equations Used for Calculating Seismic Force, V*
	For ZONE 3: C = 0.08 for bearing pressure ≥ 2000 psf (B, C) C = 0.16 for bearing pressure < 2000 psf (D, E)
1949–1958	$V = CW$ (A-6) where: $W = D$, except $W = D + L$ for warehouses (ASD) $C = 0.15/(N+4.5)$ where: N = Number of stories above story under consideration C is doubled in Zone 2 C is quadrupled in Zone 4 Consideration of soils was eliminated during this period.
1961–1973	Seismic provisions were moved to the body of code (ASD). $V = ZKCW$ (A-7) where: Z = Seismic Zone Factor $Z = 0.25, 0.5$, and 1.0 for Zones 1, 2, and 3, respectively K is related to framing system $K = 1.00$ Unless specified otherwise $K = 1.33$ for box system $K = 0.80$ for dual system 100% bracing system + 25% MRSF) $K = 0.67$ MRSF carrying 100% of lateral load $C = 0.05/(T^{(0.3333)})$, or $C = 0.1$ for 1- and 2-story buildings with uniform vertical distribution where: $T = 0.05H/(D^{(0.5)})$, or $T = 0.1N$ for moment-resisting steel frame (MRSF) carrying 100% of lateral load where: H = Height to roof (in feet) There was no “S” Factor. Site soils were not considered.
1976–1985	Zone 4 was introduced. $V = ZIKCSW$ (ASD) (A-8) where: $Z = 3/16, 3/8, 3/4$, and 1.0 for Zones 1, 2, 3, 4, respectively

Year(s)	Equations Used for Calculating Seismic Force, V
	Importance Factor, I was introduced. *I* = Importance Factor $C = 1/T^{0.5} \leq 0.12$ $CS \leq 0.14$ (Allowable Stress Design) The S-factor addresses site soils. It is related to the ratio *T/Ts* of building period, *T,* to the characteristic site period, *Ts*, established as described below. $1.0 \leq S \leq 1.5$ The range of values of *Ts* may be established from properly substantiated geotechnical data, in accordance with UBC Standard No. 23-1, except that *Ts* shall not be taken as less than 0.5 second nor more than 2.5 seconds. *Ts* shall be that value within the range of site periods, as determined above, that is nearest to *T*. When *Ts* is not properly established, the value of *S* shall be 1.5.
1988–1994	*Z* was revised to a pseudo-PGA value. $V = (ZIC/Rw)W$ (ASD) with SA limit and minimums (A-9) where: *Rw* factors are like the R factors in ASCE 7 (ASCE, 2022) but are multiplied by 1.4 $C = 1.25S/T^{0.6667}$
1997	The Load and Resistance Factor Design (LRFD) was updated with SA limit and minimums. Near-fault factors *Na* and *Nv* were added. $V = CvIW/(RT)$ (A-10) where: *Cv* = Seismic Coefficient for long-period response *R* = Response Modification Factor *T* = Fundamental Period of Vibration for the loading direction under consideration

A.3 Building Periods, *Te*

The *Te* periods tabulated in HAZUS-OSHPD, as were also used in FEMA P-154 (FEMA, 2015a), are used for building periods. A *Te* value is provided for each Model Building Type, for 1-story to 20-story buildings. For taller buildings, the 20-story *Te* value may be used if a more precise value is not offered by the Structural Engineer who is providing evaluation and retrofit design services. Users must be permitted to override the *Te* values—at least for the post-retrofit condition.

A.4 Values for *Te* and *Cs* for Model Building Types

ImageCat, Inc., compiled tables of values for *Te* and *Cs* for the Model Building Types in sections A.4.1 through A.4.14 below.

Note that in Sections A 4.1 and A.4.2, residential light-frame dwellings and apartments (W1) were constructed in California and the West according to prescriptive “conventional light-frame” rules, without formal seismic design using code lateral forces. This practice extended into the 1970s and predated the use of plywood or other engineered shear panels. Pre-1976 W1 and pre-1961 W2 are treated as "pre-code.”

A.4.1 MODEL BUILDING TYPE W1

Table A-3. *Te* and *Cs*[1] Values for Model Building Types W1/W1a (Wood Light-Frame)[2] for All Site Classes[3]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC Code*[4]	*Cs, UBC Code 1935-1946 Editions, UBC Zone 3*[4]	*Cs, UBC Code 1935-1946 Editions, UBC Zone 2*[4]	*Cs, UBC Code 1949-1958 Editions, UBC Zone 3*[4]	*Cs, UBC Code 1949-1958 Editions, UBC Zone 2*[4]	*Cs, UBC Code 1961-1973 Editions, UBC Zone 3*[4]	*Cs, UBC Code 1961-1973 Editions, UBC Zone 2*[4]
1	14	0.35	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2	24	0.38	0.09	0.09	0.09	0.09	0.09	0.09	0.09
3	34	0.49	0.08	0.08	0.08	0.08	0.08	0.08	0.08
4	44	0.6	0.07	0.07	0.07	0.07	0.07	0.07	0.07
5[5]	54	0.7	0.06	0.06	0.06	0.06	0.06	0.06	0.06

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Essentially light-frame means "pre-code", as these were built using conventional light-frame rules well into the 1970s. Also applies to manufactured homes (MH), which are limited to single-story.

[3] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.

[4] *Cs* values are set for conventional light-framed buildings (no formal code design by an engineer).

[5] Older wood-framed buildings typically have fewer than 5 stories.

Table A-4. *Cs*[1] Values for Model Building Types W1/W1a (Wood Light-Frame) for Site Class B[2]

No. of Stories	*UBC Code 1976-1985 Editions, UBC Zone 4*[3]	*UBC Code 1976-1985 Editions, UBC Zone 3*[3]	*UBC Code 1988-1994 Editions, UBC Zone 4*[3]	*UBC Code 1988-1994 Editions, UBC Zone 3*[3]	*UBC Code 1997 Edition, UBC Zone 4*[3]	*UBC Code 1997 Edition, UBC Zone 3*[3]
1	0.26	0.20	0.22	0.17	0.20	0.15
2	0.26	0.20	0.22	0.17	0.20	0.15
3	0.26	0.20	0.22	0.17	0.20	0.15
4	0.26	0.20	0.22	0.17	0.20	0.15
5[4]	0.26	0.20	0.20	0.15	0.20	0.15

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

[3] Values are for later buildings with an earthquake-resisting system formally designed under code (UBC, IBC) by a Professional Engineer (Civil or Structural)

[4] Older wood-framed buildings typically have fewer than 5 stories.

Table A-5. *Cs*[1] Values for Model Building Types W1/W1a (Wood Light-Frame) for Site Class C[2]

No. of Stories	*UBC Code 1976-1985 Editions, UBC Zone 4*[3]	*UBC Code 1976-1985 Editions, UBC Zone 3*[3]	*UBC Code 1988-1994 Editions, UBC Zone 4*[3]	*UBC Code 1988-1994 Editions, UBC Zone 3*[3]	*UBC Code 1997 Edition, UBC Zone 4*[3]	*UBC Code 1997 Edition, UBC Zone 3*[3]
1	0.26	0.20	0.22	0.17	0.20	0.17
2	0.26	0.20	0.22	0.17	0.20	0.17
3	0.26	0.20	0.22	0.17	0.20	0.17
4	0.26	0.20	0.22	0.17	0.20	0.17
5[4]	0.26	0.20	0.20	0.15	0.20	0.17

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

[3] Values are for later buildings with an earthquake-resisting system formally designed under code (UBC, IBC) by a Professional Engineer (Civil or Structural)

[4] Older wood-framed buildings typically have fewer than 5 stories.

Table A-6. *Cs*[1] Values for Model Building Types W1/W1a (Wood Light-Frame) for Site Class D[2]

No. of Stories	*UBC Code 1976-1985, UBC Zone 4*[3]	*UBC Code 1976-1985, UBC Zone 3*[3]	*UBC Code 1988-1994, UBC Zone 4*[3]	*UBC Code 1988-1994, UBC Zone 3*[3]	*UBC Code 1997, UBC Zone 4*[3]	*UBC Code 1997, UBC Zone*[3]
1	0.25	0.19	0.22	0.17	0.22	0.18
2	0.26	0.20	0.22	0.17	0.22	0.18
3	0.26	0.20	0.22	0.17	0.22	0.18
4	0.26	0.20	0.22	0.17	0.22	0.18
5[4]	0.26	0.20	0.22	0.17	0.22	0.18

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

[3] Values are for later buildings with an earthquake-resisting system formally designed under code (UBC, IBC) by a Professional Engineer (Civil or Structural)

[4] Older wood-framed buildings typically have fewer than 5 stories.

Table A-7. *Cs*[1] Values for Model Building Types W1/W1a (Wood Light-Frame) for Site Class E[2]

No. of Stories	*UBC Code 1976-1985, UBC Zone 4*[3]	*UBC Code 1976-1985, UBC Zone 3*[3]	*UBC Code 1988-1994, UBC Zone 4*[3]	*UBC Code 1988-1994, UBC Zone 3*[3]	*UBC Code 1997, UBC Zone 4*[3]	*UBC Code 1997, UBC Zone 3*[3]
1	0.24	0.18	0.22	0.17	0.18	0.18
2	0.25	0.19	0.22	0.17	0.18	0.18
3	0.26	0.19	0.22	0.17	0.18	0.18
4	0.26	0.20	0.22	0.17	0.18	0.18
5[4]	0.25	0.19	0.22	0.17	0.18	0.18

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

[3] Values are for later buildings with an earthquake-resisting system formally designed under code (UBC, IBC) by a Professional Engineer (Civil or Structural)

[4] Older wood-framed buildings typically have fewer than 5 stories.

A.4.2 MODEL BUILDING TYPE W2

Table A-8. *Te* and *Cs*[1] Values for Model Building Type W2 (Commercial/Industrial Wood-Frame), Greater than 5,000 SF, for All Site Classes

No. of Stories	Hn	Te	Cs, Pre-UBC Code	Cs, UBC Code 1935-1946 Editions, UBC Zone 3[2]	Cs, UBC Code 1935-1946 Editions, UBC Zone 2[2]	Cs, UBC Code 1949-1958 Editions, UBC Zone 3[2]	Cs, UBC Code 1949-1958 Editions, UBC Zone 2[2]
1	14	0.35	0.1	0.1	0.1	0.1	0.1
2	24	0.38	0.09	0.09	0.09	0.09	0.09
3	34	0.49	0.08	0.08	0.08	0.08	0.08
4	44	0.6	0.07	0.07	0.07	0.07	0.07
5	54	0.7	0.06	0.06	0.06	0.06	0.06

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] *Cs* values are for conventional light-framed buildings (no code design).

Table A-9. *Cs*[1] Values for Model Building Type W2 (Commercial/Industrial Wood-Frame), Greater than 5,000 SF, for Site Class B

No. of Stories	UBC Code 1961-1973 Editions, UBC Zone 3	UBC Code 1961-1973 Editions, UBC Zone 2	UBC Code 1976-1985 Editions, UBC Zone 4	UBC Code 1976-1985 Editions, UBC Zone 3	UBC Code 1988-1994 Editions, UBC Zone 4	UBC Code 1988-1994 Editions, UBC Zone 3	UBC Code 1997 Edition, UBC Zone 4	UBC Code 1997 Edition, UBC Zone 3
1	0.19	0.09	0.26	0.20	0.22	0.17	0.20	0.15
2	0.19	0.09	0.26	0.20	0.22	0.17	0.20	0.15
3	0.15	0.08	0.26	0.20	0.22	0.17	0.20	0.15
4	0.14	0.07	0.26	0.20	0.22	0.17	0.20	0.15
5	0.13	0.07	0.26	0.20	0.20	0.15	0.20	0.15

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

Table A-10. *Cs*[1] Values for Model Building Type W2 (Commercial/Industrial Wood-Frame), Greater than 5,000 SF, for Site Class C

No. of Stories	*UBC Code 1961-1973 Editions, UBC Zone 3*	*UBC Code 1961-1973 Editions, UBC Zone 2*	*UBC Code 1976-1985 Editions, UBC Zone 4*	*UBC Code 1976-1985 Editions, UBC Zone 3*	*UBC Code 1988-1994 Editions, UBC Zone 4*	*UBC Code 1988-1994 Editions, UBC Zone 3*	*UBC Code 1997 Edition, UBC Zone 4*	*UBC Code 1997 Edition, UBC Zone 3*
1	0.19	0.09	0.26	0.20	0.22	0.17	0.20	0.17
2	0.19	0.09	0.26	0.20	0.22	0.17	0.20	0.17
3	0.15	0.08	0.26	0.20	0.22	0.17	0.20	0.17
4	0.14	0.07	0.26	0.20	0.22	0.17	0.20	0.17
5	0.13	0.07	0.26	0.20	0.20	0.15	0.20	0.17

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

Table A-11. *Cs*[1] Values for Model Building Type W2 (Commercial/Industrial Wood-Frame), Greater than 5,000 SF, for Site Class D

No. of Stories	*UBC Code 1961-1973 Editions, UBC Zone 3*	*UBC Code 1961-1973 Editions, UBC Zone 2*	*UBC Code 1976-1985 Editions, UBC Zone 4*	*UBC Code 1976-1985 Editions, UBC Zone 3*	*UBC Code 1988-1994 Editions, UBC Zone 4*	*UBC Code 1988-1994 Editions, UBC Zone 3*	*UBC Code 1997 Edition, UBC Zone 4*	*UBC Code 1997 Edition, UBC Zone 3*
1	0.19	0.09	0.25	0.19	0.22	0.17	0.22	0.18
2	0.19	0.09	0.26	0.20	0.22	0.17	0.22	0.18
3	0.15	0.08	0.26	0.20	0.22	0.17	0.22	0.18
4	0.14	0.07	0.26	0.20	0.22	0.17	0.22	0.18
5	0.13	0.07	0.26	0.20	0.22	0.17	0.22	0.18

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

Table A-12. *Cs*[1] Values for Model Building Type W2 (Commercial/Industrial Wood-Frame), Greater than 5,000 SF, for Site Class E

No. of Stories								
1	0.19	0.09	0.24	0.18	0.22	0.17	0.18	0.18
2	0.19	0.09	0.25	0.19	0.22	0.17	0.18	0.18
3	0.15	0.08	0.26	0.19	0.22	0.17	0.18	0.18
4	0.14	0.07	0.26	0.20	0.22	0.17	0.18	0.18
5	0.13	0.07	0.25	0.19	0.22	0.17	0.18	0.18

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

A.4.3 MODEL BUILDING TYPE S1

Table A-13. *Te* and *Cs*[1] Values for Model Building Type S1/S1a (Steel Moment Frame) for Site Class B[2]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC[3]*	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	14	0.4	0.055	0.112	0.070	0.153	0.076	0.094	0.047	0.131	0.098	0.129	0.097	0.118	0.088
2	24	0.5	0.046	0.112	0.070	0.129	0.065	0.094	0.047	0.131	0.098	0.112	0.084	0.118	0.088
3	36	0.69	0.04	0.112	0.070	0.112	0.056	0.070	0.035	0.131	0.098	0.092	0.069	0.091	0.069
4	48	0.87	0.035	0.112	0.050	0.099	0.049	0.064	0.032	0.131	0.098	0.079	0.060	0.074	0.055
5	60	1.04	0.032	0.112	0.050	0.088	0.044	0.059	0.030	0.131	0.098	0.071	0.053	0.062	0.047
6	72	1.2	0.029	0.112	0.050	0.080	0.040	0.056	0.028	0.115	0.086	0.065	0.049	0.054	0.041
7	84	1.36	0.026	0.112	0.050	0.073	0.037	0.053	0.026	0.099	0.075	0.060	0.045	0.048	0.036
8	96	1.51	0.024	0.112	0.040	0.067	0.034	0.051	0.025	0.084	0.063	0.056	0.042	0.044	0.033
9	108	1.66	0.022	0.112	0.040	0.062	0.031	0.049	0.024	0.068	0.051	0.053	0.040	0.044	0.033
10	120	1.81	0.021	0.112	0.040	0.058	0.029	0.047	0.023	0.063	0.047	0.050	0.038	0.044	0.033
11	132	1.95	0.019	0.112	0.040	0.054	0.027	0.045	0.023	0.060	0.045	0.048	0.036	0.044	0.033
12	144	2.09	0.018	0.112	0.040	0.051	0.025	0.044	0.022	0.057	0.043	0.046	0.034	0.044	0.033
13	156	2.23	0.017	0.112	0.040	0.048	0.024	0.043	0.021	0.055	0.041	0.044	0.033	0.044	0.033
14	168	2.36	0.016	0.112	0.040	0.045	0.023	0.042	0.021	0.053	0.040	0.042	0.032	0.044	0.033
15	180	2.5	0.015	0.112	0.040	0.043	0.022	0.041	0.020	0.051	0.038	0.042	0.032	0.044	0.033
16	192	2.63	0.015	0.112	0.040	0.041	0.020	0.040	0.020	0.049	0.037	0.042	0.032	0.044	0.033
17	204	2.76	0.014	0.112	0.040	0.039	0.020	0.039	0.020	0.048	0.036	0.042	0.032	0.044	0.033
18	216	2.89	0.013	0.112	0.040	0.037	0.019	0.039	0.019	0.047	0.035	0.042	0.032	0.044	0.033
19	228	3.02	0.013	0.112	0.040	0.036	0.018	0.038	0.019	0.045	0.034	0.042	0.032	0.044	0.033
20+	240	3.14	0.012	0.112	0.040	0.034	0.017	0.037	0.019	0.044	0.033	0.042	0.032	0.044	0.033

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.
[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.
[3] Pre-UBC *Cs* taken from pre-1961 *Cs* for UBC Seismic Zone 3, as deduced from Table A-2b in FEMA P-155 (3rd Ed.) (FEMA, 2015b).

Table A-14. *Cs*[1] Values for Model Building Type S1/S1a (Steel Moment Frame) for Site Class C[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.070	0.153	0.076	0.094	0.047	0.131	0.098	0.129	0.097	0.118	0.097
2	0.112	0.070	0.129	0.065	0.094	0.047	0.131	0.098	0.112	0.084	0.118	0.097
3	0.112	0.070	0.112	0.056	0.070	0.035	0.131	0.098	0.092	0.069	0.118	0.097
4	0.112	0.050	0.099	0.049	0.064	0.032	0.131	0.098	0.079	0.060	0.103	0.083
5	0.112	0.050	0.088	0.044	0.059	0.030	0.131	0.098	0.071	0.053	0.087	0.070
6	0.112	0.050	0.080	0.040	0.056	0.028	0.120	0.090	0.065	0.049	0.076	0.061
7	0.112	0.050	0.073	0.037	0.053	0.026	0.109	0.081	0.060	0.045	0.068	0.055
8	0.112	0.040	0.067	0.034	0.051	0.025	0.097	0.073	0.056	0.042	0.061	0.049
9	0.112	0.040	0.062	0.031	0.049	0.024	0.086	0.065	0.053	0.040	0.056	0.045
10	0.112	0.040	0.058	0.029	0.047	0.023	0.075	0.056	0.050	0.038	0.052	0.042
11	0.112	0.040	0.054	0.027	0.045	0.023	0.064	0.048	0.048	0.036	0.048	0.039
12	0.112	0.040	0.051	0.025	0.044	0.022	0.057	0.043	0.046	0.034	0.045	0.036
13	0.112	0.040	0.048	0.024	0.043	0.021	0.055	0.041	0.044	0.033	0.044	0.036
14	0.112	0.040	0.045	0.023	0.042	0.021	0.053	0.040	0.042	0.032	0.044	0.036
15	0.112	0.040	0.043	0.022	0.041	0.020	0.051	0.038	0.042	0.032	0.044	0.036
16	0.112	0.040	0.041	0.020	0.040	0.020	0.049	0.037	0.042	0.032	0.044	0.036
17	0.112	0.040	0.039	0.020	0.039	0.020	0.048	0.036	0.042	0.032	0.044	0.036
18	0.112	0.040	0.037	0.019	0.039	0.019	0.047	0.035	0.042	0.032	0.044	0.036
19	0.112	0.040	0.036	0.018	0.038	0.019	0.045	0.034	0.042	0.032	0.044	0.036
20+	0.112	0.040	0.034	0.017	0.037	0.019	0.044	0.033	0.042	0.032	0.044	0.036

[1] Lateral Force Coefficient, Cs, in ultimate strength units.

[2] Values are from the UBC editions indicated.

Table A-15. *Cs*[1] Values for Model Building Type S1/S1a (Steel Moment Frame) for Site Class D[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.070	0.153	0.076	0.094	0.047	0.126	0.094	0.129	0.097	0.129	0.106
2	0.112	0.070	0.129	0.065	0.094	0.047	0.131	0.098	0.129	0.097	0.129	0.106
3	0.112	0.070	0.112	0.056	0.070	0.035	0.131	0.098	0.110	0.082	0.129	0.106
4	0.112	0.050	0.099	0.049	0.064	0.032	0.131	0.098	0.095	0.071	0.118	0.100
5	0.112	0.050	0.088	0.044	0.059	0.030	0.126	0.095	0.085	0.064	0.100	0.084
6	0.112	0.050	0.080	0.040	0.056	0.028	0.119	0.089	0.078	0.058	0.087	0.073
7	0.112	0.050	0.073	0.037	0.053	0.026	0.112	0.084	0.072	0.054	0.078	0.065
8	0.112	0.040	0.067	0.034	0.051	0.025	0.105	0.079	0.067	0.050	0.070	0.059
9	0.112	0.040	0.062	0.031	0.049	0.024	0.099	0.074	0.063	0.048	0.064	0.054
10	0.112	0.040	0.058	0.029	0.047	0.023	0.094	0.070	0.060	0.045	0.059	0.050
11	0.112	0.040	0.054	0.027	0.045	0.023	0.089	0.067	0.057	0.043	0.055	0.047
12	0.112	0.040	0.051	0.025	0.044	0.022	0.086	0.064	0.055	0.041	0.052	0.044
13	0.112	0.040	0.048	0.024	0.043	0.021	0.082	0.062	0.053	0.040	0.049	0.041
14	0.112	0.040	0.045	0.023	0.042	0.021	0.079	0.059	0.051	0.038	0.048	0.040
15	0.112	0.040	0.043	0.022	0.041	0.020	0.076	0.057	0.049	0.037	0.048	0.040
16	0.112	0.040	0.041	0.020	0.040	0.020	0.073	0.054	0.048	0.036	0.048	0.040
17	0.112	0.040	0.039	0.020	0.039	0.020	0.069	0.052	0.046	0.035	0.048	0.040
18	0.112	0.040	0.037	0.019	0.039	0.019	0.066	0.050	0.045	0.034	0.048	0.040
19	0.112	0.040	0.036	0.018	0.038	0.019	0.063	0.048	0.044	0.033	0.048	0.040
20+	0.112	0.040	0.034	0.017	0.037	0.019	0.060	0.045	0.043	0.032	0.048	0.040

[1] Lateral Force Coefficient, Cs, in ultimate strength units.

[2] Values are from the UBC editions indicated.

Table A-16. *Cs*[1] Values for Model Building Type S1/S1a (Steel Moment Frame) for Site Class E[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	
1	0.224	0.070	0.153	0.076	0.094	0.047	0.120	0.090	0.129	0.097	0.106	0.106
2	0.224	0.070	0.129	0.065	0.094	0.047	0.127	0.095	0.129	0.097	0.106	0.106
3	0.224	0.070	0.112	0.056	0.070	0.035	0.131	0.098	0.129	0.097	0.106	0.106
4	0.224	0.050	0.099	0.049	0.064	0.032	0.122	0.091	0.119	0.089	0.106	0.106
5	0.224	0.050	0.088	0.044	0.059	0.030	0.113	0.085	0.106	0.080	0.106	0.106
6	0.224	0.050	0.080	0.040	0.056	0.028	0.107	0.080	0.097	0.073	0.106	0.106
7	0.224	0.050	0.073	0.037	0.053	0.026	0.101	0.076	0.090	0.067	0.106	0.102
8	0.224	0.040	0.067	0.034	0.051	0.025	0.097	0.073	0.084	0.063	0.105	0.092
9	0.224	0.040	0.062	0.031	0.049	0.024	0.094	0.070	0.079	0.060	0.096	0.084
10	0.224	0.040	0.058	0.029	0.047	0.023	0.090	0.068	0.075	0.056	0.089	0.078
11	0.224	0.040	0.054	0.027	0.045	0.023	0.087	0.065	0.072	0.054	0.083	0.073
12	0.224	0.040	0.051	0.025	0.044	0.022	0.084	0.063	0.069	0.052	0.078	0.068
13	0.224	0.040	0.048	0.024	0.043	0.021	0.082	0.061	0.066	0.050	0.073	0.064
14	0.224	0.040	0.045	0.023	0.042	0.021	0.079	0.059	0.064	0.048	0.069	0.061
15	0.224	0.040	0.043	0.022	0.041	0.020	0.077	0.057	0.061	0.046	0.066	0.057
16	0.224	0.040	0.041	0.020	0.040	0.020	0.074	0.056	0.060	0.045	0.063	0.055
17	0.224	0.040	0.039	0.020	0.039	0.020	0.072	0.054	0.058	0.043	0.060	0.052
18	0.224	0.040	0.037	0.019	0.039	0.019	0.069	0.052	0.056	0.042	0.057	0.050
19	0.224	0.040	0.036	0.018	0.038	0.019	0.067	0.050	0.055	0.041	0.055	0.048
20+	0.224	0.040	0.034	0.017	0.037	0.019	0.065	0.049	0.053	0.040	0.053	0.046

[1] Lateral Force Coefficient, Cs, in ultimate strength units.

[2] Values are from the UBC editions indicated.

A.4.4 MODEL BUILDING TYPE S2

Table A-17. *Te* and *Cs*[1] Values for Model Building Type S2 (Steel Braced Frame) for Site Class B

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC*[2]	*Cs, Code 1935-1946, Zone 3*	*Cs, Code 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	14	0.4	0.055	0.112	0.070	0.153	0.076	0.140	0.070	0.196	0.147	0.196	0.147	0.179	0.134
2	24	0.43	0.046	0.112	0.070	0.129	0.065	0.140	0.070	0.196	0.147	0.196	0.147	0.179	0.134
3	36	0.59	0.04	0.112	0.070	0.112	0.056	0.108	0.054	0.196	0.147	0.196	0.147	0.179	0.134
4	48	0.73	0.035	0.112	0.050	0.099	0.049	0.100	0.050	0.196	0.147	0.183	0.137	0.179	0.134
5	60	0.86	0.032	0.112	0.050	0.088	0.044	0.095	0.047	0.196	0.147	0.163	0.123	0.177	0.133
6	72	0.99	0.029	0.112	0.050	0.080	0.040	0.090	0.045	0.196	0.147	0.149	0.112	0.154	0.116
7	84	1.11	0.026	0.112	0.050	0.073	0.037	0.087	0.044	0.191	0.143	0.138	0.104	0.137	0.103
8	96	1.22	0.024	0.112	0.040	0.067	0.034	0.084	0.042	0.178	0.133	0.129	0.097	0.124	0.093
9	108	1.34	0.022	0.112	0.040	0.062	0.031	0.082	0.041	0.165	0.124	0.122	0.091	0.114	0.085
10	120	1.45	0.021	0.112	0.040	0.058	0.029	0.080	0.040	0.153	0.115	0.116	0.087	0.105	0.079
11	132	1.55	0.019	0.112	0.040	0.054	0.027	0.078	0.039	0.142	0.106	0.110	0.083	0.098	0.073
12	144	1.66	0.018	0.112	0.040	0.051	0.025	0.076	0.038	0.130	0.098	0.105	0.079	0.092	0.069
13	156	1.76	0.017	0.112	0.040	0.048	0.024	0.075	0.037	0.119	0.089	0.101	0.076	0.086	0.065
14	168	1.86	0.016	0.112	0.040	0.045	0.023	0.073	0.037	0.108	0.081	0.098	0.073	0.082	0.061
15	180	1.96	0.015	0.112	0.040	0.043	0.022	0.072	0.036	0.097	0.073	0.094	0.071	0.078	0.058
16	192	2.06	0.015	0.112	0.040	0.041	0.020	0.071	0.035	0.095	0.071	0.091	0.069	0.074	0.055
17	204	2.15	0.014	0.112	0.040	0.039	0.020	0.070	0.035	0.093	0.070	0.089	0.066	0.071	0.053
18	216	2.25	0.013	0.112	0.040	0.037	0.019	0.069	0.034	0.091	0.068	0.086	0.065	0.068	0.051
19	228	2.34	0.013	0.112	0.040	0.036	0.018	0.068	0.034	0.089	0.067	0.084	0.063	0.065	0.049
20+	240	2.43	0.012	0.112	0.040	0.034	0.017	0.067	0.033	0.087	0.065	0.082	0.061	0.063	0.047

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.
[2] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

Table A-18. *Cs*[1] Values for Model Building Type S2 (Steel Braced Frame) for Site Class C

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC Code 1997, Zone 4	UBC Code 1997, Zone 3
1	0.112	0.070	0.153	0.076	0.140	0.070	0.196	0.147	0.196	0.147	0.179	0.147
2	0.112	0.070	0.129	0.065	0.140	0.070	0.196	0.147	0.196	0.147	0.179	0.147
3	0.112	0.070	0.112	0.056	0.108	0.054	0.196	0.147	0.196	0.147	0.179	0.147
4	0.112	0.050	0.099	0.049	0.100	0.050	0.196	0.147	0.183	0.137	0.179	0.147
5	0.112	0.050	0.088	0.044	0.095	0.047	0.196	0.147	0.163	0.123	0.179	0.147
6	0.112	0.050	0.080	0.040	0.090	0.045	0.196	0.147	0.149	0.112	0.179	0.147
7	0.112	0.050	0.073	0.037	0.087	0.044	0.194	0.146	0.138	0.104	0.179	0.147
8	0.112	0.040	0.067	0.034	0.084	0.042	0.184	0.138	0.129	0.097	0.174	0.140
9	0.112	0.040	0.062	0.031	0.082	0.041	0.174	0.131	0.122	0.091	0.159	0.128
10	0.112	0.040	0.058	0.029	0.080	0.040	0.165	0.124	0.116	0.087	0.147	0.118
11	0.112	0.040	0.054	0.027	0.078	0.039	0.157	0.118	0.110	0.083	0.137	0.110
12	0.112	0.040	0.051	0.025	0.076	0.038	0.149	0.112	0.105	0.079	0.128	0.103
13	0.112	0.040	0.048	0.024	0.075	0.037	0.141	0.106	0.101	0.076	0.121	0.097
14	0.112	0.040	0.045	0.023	0.073	0.037	0.133	0.100	0.098	0.073	0.114	0.092
15	0.112	0.040	0.043	0.022	0.072	0.036	0.125	0.094	0.094	0.071	0.109	0.087
16	0.112	0.040	0.041	0.020	0.071	0.035	0.118	0.088	0.091	0.069	0.103	0.083
17	0.112	0.040	0.039	0.020	0.070	0.035	0.110	0.083	0.089	0.066	0.099	0.079
18	0.112	0.040	0.037	0.019	0.069	0.034	0.103	0.077	0.086	0.065	0.095	0.076
19	0.112	0.040	0.036	0.018	0.068	0.034	0.095	0.071	0.084	0.063	0.091	0.073
20+	0.112	0.040	0.034	0.017	0.067	0.033	0.088	0.066	0.082	0.061	0.088	0.070

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

Table A-19. *Cs*[1] Values for Model Building Type S2 (Steel Braced Frame) for Site Class D

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC Code 1997, Zone 4	UBC Code 1997, Zone 3
1	0.112	0.070	0.153	0.076	0.140	0.070	0.191	0.144	0.196	0.147	0.196	0.161
2	0.112	0.070	0.129	0.065	0.140	0.070	0.196	0.147	0.196	0.147	0.196	0.161
3	0.112	0.070	0.112	0.056	0.108	0.054	0.196	0.147	0.196	0.147	0.196	0.161
4	0.112	0.050	0.099	0.049	0.100	0.050	0.196	0.147	0.196	0.147	0.196	0.161
5	0.112	0.050	0.088	0.044	0.095	0.047	0.196	0.147	0.196	0.147	0.196	0.161
6	0.112	0.050	0.080	0.040	0.090	0.045	0.194	0.145	0.179	0.134	0.196	0.161
7	0.112	0.050	0.073	0.037	0.087	0.044	0.186	0.140	0.166	0.124	0.196	0.161
8	0.112	0.040	0.067	0.034	0.084	0.042	0.180	0.135	0.155	0.116	0.196	0.161
9	0.112	0.040	0.062	0.031	0.082	0.041	0.174	0.130	0.146	0.110	0.182	0.154
10	0.112	0.040	0.058	0.029	0.080	0.040	0.169	0.126	0.139	0.104	0.168	0.142
11	0.112	0.040	0.054	0.027	0.078	0.039	0.163	0.123	0.132	0.099	0.157	0.132
12	0.112	0.040	0.051	0.025	0.076	0.038	0.159	0.119	0.127	0.095	0.147	0.124
13	0.112	0.040	0.048	0.024	0.075	0.037	0.154	0.115	0.122	0.091	0.138	0.117
14	0.112	0.040	0.045	0.023	0.073	0.037	0.150	0.112	0.117	0.088	0.131	0.110
15	0.112	0.040	0.043	0.022	0.072	0.036	0.146	0.109	0.113	0.085	0.124	0.105
16	0.112	0.040	0.041	0.020	0.071	0.035	0.142	0.107	0.110	0.082	0.118	0.100
17	0.112	0.040	0.039	0.020	0.070	0.035	0.139	0.104	0.106	0.080	0.113	0.095
18	0.112	0.040	0.037	0.019	0.069	0.034	0.136	0.102	0.103	0.078	0.108	0.091
19	0.112	0.040	0.036	0.018	0.068	0.034	0.134	0.100	0.101	0.075	0.104	0.088
20+	0.112	0.040	0.034	0.017	0.067	0.033	0.131	0.098	0.098	0.074	0.100	0.084

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

Table A-20. *Cs*[1] Values for Model Building Type S2 (Steel Braced Frame) for Site Class E

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC Code 1997, Zone 4	UBC Code 1997, Zone 3
1	0.224	0.070	0.153	0.076	0.140	0.070	0.181	0.136	0.196	0.147	0.161	0.161
2	0.224	0.070	0.129	0.065	0.140	0.070	0.189	0.142	0.196	0.147	0.161	0.161
3	0.224	0.070	0.112	0.056	0.108	0.054	0.196	0.147	0.196	0.147	0.161	0.161
4	0.224	0.050	0.099	0.049	0.100	0.050	0.192	0.144	0.196	0.147	0.161	0.161
5	0.224	0.050	0.088	0.044	0.095	0.047	0.181	0.136	0.196	0.147	0.161	0.161
6	0.224	0.050	0.080	0.040	0.090	0.045	0.173	0.130	0.196	0.147	0.161	0.161
7	0.224	0.050	0.073	0.037	0.087	0.044	0.167	0.125	0.196	0.147	0.161	0.161
8	0.224	0.040	0.067	0.034	0.084	0.042	0.161	0.121	0.194	0.145	0.161	0.161
9	0.224	0.040	0.062	0.031	0.082	0.041	0.157	0.118	0.183	0.137	0.161	0.161
10	0.224	0.040	0.058	0.029	0.080	0.040	0.153	0.115	0.173	0.130	0.161	0.161
11	0.224	0.040	0.054	0.027	0.078	0.039	0.149	0.112	0.165	0.124	0.161	0.161
12	0.224	0.040	0.051	0.025	0.076	0.038	0.146	0.110	0.158	0.119	0.161	0.161
13	0.224	0.040	0.048	0.024	0.075	0.037	0.144	0.108	0.152	0.114	0.161	0.161
14	0.224	0.040	0.045	0.023	0.073	0.037	0.141	0.106	0.146	0.110	0.161	0.161
15	0.224	0.040	0.043	0.022	0.072	0.036	0.139	0.104	0.142	0.106	0.161	0.161
16	0.224	0.040	0.041	0.020	0.071	0.035	0.136	0.102	0.137	0.103	0.161	0.155
17	0.224	0.040	0.039	0.020	0.070	0.035	0.134	0.101	0.133	0.100	0.161	0.148
18	0.224	0.040	0.037	0.019	0.069	0.034	0.132	0.099	0.129	0.097	0.161	0.142
19	0.224	0.040	0.036	0.018	0.068	0.034	0.130	0.098	0.126	0.094	0.156	0.136
20+	0.224	0.040	0.034	0.017	0.067	0.033	0.128	0.096	0.123	0.092	0.150	0.131

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

A.4.5 MODEL BUILDING TYPE S3

Table A-21. *Te* and *Cs*[1] Values for Model Building Type S3 (Steel Light Frame)[2] for Site Class B

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC*[3]	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	15	0.35	0.055	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.393	0.295	0.357	0.268
2	25	0.39	0.046	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.393	0.295	0.357	0.268
3[4]	35	0.5	0.04	—	—	—	—	—	—	—	—	—	—	—	—

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Includes "Butler" type buildings, with moment frame bents in the transverse direction and steel rod-bracing in the longitudinal direction. Wind loads may control design of the lateral system, so *Cs* may increase.

[3] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

[4] There are few 3-story buildings that are Type S3.

Table A-22. *Cs*[1] Values for Model Building Type S3 (Steel Light Frame)[2] for Site Class C

No. of Stories[3]	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.393	0.295	0.357	0.295
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.393	0.295	0.357	0.295

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Includes "Butler" type buildings, with moment frame bents in the transverse direction and steel rod-bracing in the longitudinal direction. Wind loads may control design of the lateral system, so *Cs* may increase.

[3] There are few 3-story buildings that are Type S3.

Table A-23. *Cs*[1] Values for Model Building Type S3 (Steel Light Frame)[2] for Site Class D

No. of Stories[3]	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.393	0.295	0.393	0.321
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.393	0.295	0.393	0.321

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Includes "Butler" type buildings, with moment frame bents in the transverse direction and steel rod-bracing in the longitudinal direction. Wind loads may control design of the lateral system, so *Cs* may increase.

[3] There are few 3-story buildings that are Type S3.

Table A-24. *Cs*[1] Values for Model Building Type S3 (Steel Light Frame)[2] for Site Class E

No. of Stories[3]	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.224	0.100	0.153	0.076	0.186	0.093	0.254	0.191	0.393	0.295	0.321	0.321
2	0.224	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.393	0.295	0.321	0.321

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Includes "Butler" type buildings, with moment frame bents in the transverse direction and steel rod-bracing in the longitudinal direction. Wind loads may control design of the lateral system, so *Cs* may increase.

[3] There are few 3-story buildings that are Type S3.

A.4.6 MODEL BUILDING TYPE S4

Table A-25. *Te* and *Cs*[1] Values for Model Building Type S4 (Steel Frame with Cast-In Place Concrete Shear Walls) for Site Class B[2]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC*[3]	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	14	0.35	0.055	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
2	24	0.35	0.046	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
3	36	0.44	0.04	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.167
4	48	0.55	0.035	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.167
5	60	0.65	0.032	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.167
6	72	0.74	0.029	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.206	0.155
7	84	0.84	0.026	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.184	0.138
8	96	0.92	0.024	0.112	0.060	0.067	0.034	0.115	0.057	0.249	0.187	0.176	0.132	0.166	0.125
9	108	1.01	0.022	0.112	0.060	0.062	0.031	0.111	0.056	0.233	0.175	0.166	0.125	0.152	0.114
10	120	1.09	0.021	0.112	0.060	0.058	0.029	0.108	0.054	0.218	0.164	0.158	0.118	0.141	0.105
11	132	1.17	0.019	0.112	0.060	0.054	0.027	0.106	0.053	0.204	0.153	0.150	0.113	0.131	0.098
12	144	1.25	0.018	0.112	0.060	0.051	0.025	0.104	0.052	0.190	0.142	0.144	0.108	0.123	0.092
13	156	1.33	0.017	0.112	0.060	0.048	0.024	0.102	0.051	0.176	0.132	0.138	0.104	0.115	0.087
14	168	1.4	0.016	0.112	0.060	0.045	0.023	0.100	0.050	0.162	0.122	0.133	0.100	0.109	0.082
15	180	1.48	0.015	0.112	0.060	0.043	0.022	0.098	0.049	0.149	0.111	0.129	0.097	0.104	0.078
16	192	1.55	0.015	0.112	0.060	0.041	0.020	0.096	0.048	0.135	0.101	0.125	0.094	0.099	0.074
17	204	1.62	0.014	0.112	0.060	0.039	0.020	0.095	0.047	0.128	0.096	0.121	0.091	0.094	0.071
18	216	1.7	0.013	0.112	0.060	0.037	0.019	0.094	0.047	0.125	0.094	0.118	0.088	0.090	0.068
19	228	1.77	0.013	0.112	0.060	0.036	0.018	0.092	0.046	0.123	0.092	0.114	0.086	0.087	0.065
20+	240	1.84	0.012	0.112	0.060	0.034	0.017	0.091	0.046	0.120	0.090	0.112	0.084	0.084	0.063

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.
[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.
[3] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

Table A-26. *Cs*[1] Values for Model Building Type S4 (Steel Frame with Cast-In Place Concrete Shear Walls) for Site Class C[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.183
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.183
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.183
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.222	0.183
7	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.222	0.183
8	0.112	0.060	0.067	0.034	0.115	0.057	0.254	0.191	0.176	0.132	0.222	0.183
9	0.112	0.060	0.062	0.031	0.111	0.056	0.242	0.182	0.166	0.125	0.213	0.171
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.158	0.118	0.197	0.158
11	0.112	0.060	0.054	0.027	0.106	0.053	0.220	0.165	0.150	0.113	0.183	0.147
12	0.112	0.060	0.051	0.025	0.104	0.052	0.210	0.157	0.144	0.108	0.172	0.138
13	0.112	0.060	0.048	0.024	0.102	0.051	0.200	0.150	0.138	0.104	0.162	0.130
14	0.112	0.060	0.045	0.023	0.100	0.050	0.190	0.143	0.133	0.100	0.153	0.123
15	0.112	0.060	0.043	0.022	0.098	0.049	0.181	0.135	0.129	0.097	0.145	0.117
16	0.112	0.060	0.041	0.020	0.096	0.048	0.171	0.128	0.125	0.094	0.138	0.111
17	0.112	0.060	0.039	0.020	0.095	0.047	0.162	0.121	0.121	0.091	0.132	0.106
18	0.112	0.060	0.037	0.019	0.094	0.047	0.153	0.115	0.118	0.088	0.127	0.102
19	0.112	0.060	0.036	0.018	0.092	0.046	0.144	0.108	0.114	0.086	0.122	0.098
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.135	0.101	0.112	0.084	0.117	0.094

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

Table A-27. *Cs*[1] Values for Model Building Type S4 (Steel Frame with Cast-In Place Concrete Shear Walls) for Site Class D[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.112	0.100	0.153	0.076	0.186	0.093	0.253	0.189	0.256	0.192	0.244	0.200
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.244	0.200
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.244	0.200
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.244	0.200
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.256	0.192	0.244	0.200
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.244	0.183	0.244	0.200
7	0.112	0.070	0.073	0.037	0.119	0.059	0.254	0.190	0.226	0.170	0.244	0.200
8	0.112	0.060	0.067	0.034	0.115	0.057	0.245	0.184	0.212	0.159	0.244	0.200
9	0.112	0.060	0.062	0.031	0.111	0.056	0.238	0.178	0.200	0.150	0.243	0.200
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.189	0.142	0.225	0.190
11	0.112	0.060	0.054	0.027	0.106	0.053	0.224	0.168	0.181	0.135	0.209	0.177
12	0.112	0.060	0.051	0.025	0.104	0.052	0.218	0.164	0.173	0.130	0.196	0.165
13	0.112	0.060	0.048	0.024	0.102	0.051	0.212	0.159	0.166	0.125	0.185	0.156
14	0.112	0.060	0.045	0.023	0.100	0.050	0.206	0.155	0.160	0.120	0.175	0.147
15	0.112	0.060	0.043	0.022	0.098	0.049	0.201	0.151	0.155	0.116	0.166	0.140
16	0.112	0.060	0.041	0.020	0.096	0.048	0.196	0.147	0.150	0.112	0.158	0.133
17	0.112	0.060	0.039	0.020	0.095	0.047	0.192	0.144	0.145	0.109	0.151	0.127
18	0.112	0.060	0.037	0.019	0.094	0.047	0.188	0.141	0.141	0.106	0.145	0.122
19	0.112	0.060	0.036	0.018	0.092	0.046	0.184	0.138	0.137	0.103	0.139	0.117
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.181	0.135	0.134	0.100	0.134	0.113

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

Table A-28. ***Cs*[1] Values for Model Building Type S4 (Steel Frame with Cast-In Place Concrete Shear Walls) for Site Class E[2]**

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.224	0.100	0.153	0.076	0.186	0.093	0.240	0.180	0.256	0.192	0.200	0.200
2	0.224	0.100	0.129	0.065	0.186	0.093	0.250	0.187	0.256	0.192	0.200	0.200
3	0.224	0.100	0.112	0.056	0.147	0.073	0.258	0.194	0.256	0.192	0.200	0.200
4	0.224	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.200	0.200
5	0.224	0.070	0.088	0.044	0.129	0.064	0.247	0.185	0.256	0.192	0.200	0.200
6	0.224	0.070	0.080	0.040	0.123	0.062	0.236	0.177	0.256	0.192	0.200	0.200
7	0.224	0.070	0.073	0.037	0.119	0.059	0.227	0.170	0.256	0.192	0.200	0.200
8	0.224	0.060	0.067	0.034	0.115	0.057	0.219	0.165	0.256	0.192	0.200	0.200
9	0.224	0.060	0.062	0.031	0.111	0.056	0.213	0.160	0.250	0.187	0.200	0.200
10	0.224	0.060	0.058	0.029	0.108	0.054	0.208	0.156	0.237	0.178	0.200	0.200
11	0.224	0.060	0.054	0.027	0.106	0.053	0.203	0.153	0.226	0.169	0.200	0.200
12	0.224	0.060	0.051	0.025	0.104	0.052	0.199	0.149	0.216	0.162	0.200	0.200
13	0.224	0.060	0.048	0.024	0.102	0.051	0.195	0.147	0.208	0.156	0.200	0.200
14	0.224	0.060	0.045	0.023	0.100	0.050	0.192	0.144	0.200	0.150	0.200	0.200
15	0.224	0.060	0.043	0.022	0.098	0.049	0.189	0.142	0.193	0.145	0.200	0.200
16	0.224	0.060	0.041	0.020	0.096	0.048	0.186	0.139	0.187	0.140	0.200	0.200
17	0.224	0.060	0.039	0.020	0.095	0.047	0.183	0.137	0.182	0.136	0.200	0.198
18	0.224	0.060	0.037	0.019	0.094	0.047	0.180	0.135	0.176	0.132	0.200	0.190
19	0.224	0.060	0.036	0.018	0.092	0.046	0.178	0.133	0.172	0.129	0.200	0.182
20+	0.224	0.060	0.034	0.017	0.091	0.046	0.175	0.132	0.167	0.126	0.200	0.175

[1] Lateral Force Coefficient, *Cs*, in ultimate strength units.

[2] Values are from the UBC editions indicated.

A.4.7 MODEL BUILDING TYPE S5

Table A-29. *Te* and *Cs* Values for Model Building Type S5 (Steel Frame with URM Infill Shear Walls)[1]

No. of Stories	*Hn*	*Te*	*Cs*[2]
1	14	0.35	0.055
2	24	0.35	0.046
3	36	0.44	0.04
4	48	0.55	0.035
5	60	0.65	0.032
6	72	0.74	0.029
7	84	0.84	0.026
8	96	0.92	0.024
9	108	1.01	0.022
10	120	1.09	0.021
11	132	1.17	0.019
12	144	1.25	0.018
13	156	1.33	0.017
14	168	1.4	0.016
15	180	1.48	0.015
16	192	1.55	0.015
17	204	1.62	0.014
18	216	1.7	0.013
19	228	1.77	0.013
20+	240	1.84	0.012

[1] URM Infill structures are all Pre-code in UBC jurisdictions, regardless of year built. All values are from HAZUS-OSHPD.

[2] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

A.4.8 MODEL BUILDING TYPE C1

Table A-30. *Te* and *Cs*[1] Values for Model Building Type C1 (Reinforced Concrete Moment Frame) for Site Class B[2]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC[3]*	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	12	0.4	0.055	0.112	0.080	0.153	0.076	0.094	0.047	0.131	0.098	0.129	0.097	0.118	0.088
2	20	0.4	0.046	0.112	0.080	0.129	0.065	0.094	0.047	0.131	0.098	0.124	0.093	0.118	0.088
3	30	0.48	0.04	0.112	0.080	0.112	0.056	0.070	0.035	0.131	0.098	0.102	0.076	0.107	0.080
4	40	0.62	0.035	0.112	0.070	0.099	0.049	0.064	0.032	0.131	0.098	0.088	0.066	0.086	0.065
5	50	0.76	0.032	0.112	0.070	0.088	0.044	0.059	0.030	0.131	0.098	0.079	0.059	0.073	0.055
6	60	0.89	0.029	0.112	0.070	0.080	0.040	0.056	0.028	0.115	0.086	0.072	0.054	0.063	0.048
7	70	1.03	0.026	0.112	0.070	0.073	0.037	0.053	0.026	0.099	0.075	0.066	0.050	0.057	0.042
8	80	1.06	0.024	0.112	0.040	0.067	0.034	0.051	0.025	0.084	0.063	0.062	0.047	0.051	0.038
9	90	1.29	0.022	0.112	0.040	0.062	0.031	0.049	0.024	0.068	0.051	0.059	0.044	0.047	0.035
10	100	1.41	0.021	0.112	0.040	0.058	0.029	0.047	0.023	0.063	0.047	0.056	0.042	0.044	0.033
11	110	1.54	0.019	0.112	0.040	0.054	0.027	0.045	0.023	0.060	0.045	0.053	0.040	0.044	0.033
12	120	1.67	0.018	0.112	0.040	0.051	0.025	0.044	0.022	0.057	0.043	0.051	0.038	0.044	0.033
13	130	1.79	0.017	0.112	0.040	0.048	0.024	0.043	0.021	0.055	0.041	0.049	0.037	0.044	0.033
14	140	1.91	0.016	0.112	0.040	0.045	0.023	0.042	0.021	0.053	0.040	0.047	0.035	0.044	0.033
15	150	2.04	0.015	0.112	0.040	0.043	0.022	0.041	0.020	0.051	0.038	0.045	0.034	0.044	0.033
16	160	2.16	0.015	0.112	0.040	0.041	0.020	0.040	0.020	0.049	0.037	0.044	0.033	0.044	0.033
17	170	2.28	0.014	0.112	0.040	0.039	0.020	0.039	0.020	0.048	0.036	0.043	0.032	0.044	0.033
18	180	2.4	0.013	0.112	0.040	0.037	0.019	0.039	0.019	0.047	0.035	0.042	0.032	0.044	0.033
19	190	2.52	0.013	0.112	0.040	0.036	0.018	0.038	0.019	0.045	0.034	0.042	0.032	0.044	0.033
20+	200	2.64	0.012	0.112	0.040	0.034	0.017	0.037	0.019	0.044	0.033	0.042	0.032	0.044	0.033

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units
[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.
[3] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC,2022).

Table A-31. *Cs*[1] Values for Model Building Type C1 (Reinforced Concrete Moment Frame) for Site Class C[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.080	0.153	0.076	0.094	0.047	0.131	0.098	0.129	0.097	0.118	0.097
2	0.112	0.080	0.129	0.065	0.094	0.047	0.131	0.098	0.124	0.093	0.118	0.097
3	0.112	0.080	0.112	0.056	0.070	0.035	0.131	0.098	0.102	0.076	0.118	0.097
4	0.112	0.070	0.099	0.049	0.064	0.032	0.131	0.098	0.088	0.066	0.118	0.097
5	0.112	0.070	0.088	0.044	0.059	0.030	0.131	0.098	0.079	0.059	0.102	0.082
6	0.112	0.070	0.080	0.040	0.056	0.028	0.120	0.090	0.072	0.054	0.089	0.071
7	0.112	0.070	0.073	0.037	0.053	0.026	0.109	0.081	0.066	0.050	0.079	0.064
8	0.112	0.040	0.067	0.034	0.051	0.025	0.097	0.073	0.062	0.047	0.072	0.058
9	0.112	0.040	0.062	0.031	0.049	0.024	0.086	0.065	0.059	0.044	0.066	0.053
10	0.112	0.040	0.058	0.029	0.047	0.023	0.075	0.056	0.056	0.042	0.061	0.049
11	0.112	0.040	0.054	0.027	0.045	0.023	0.064	0.048	0.053	0.040	0.056	0.045
12	0.112	0.040	0.051	0.025	0.044	0.022	0.057	0.043	0.051	0.038	0.053	0.042
13	0.112	0.040	0.048	0.024	0.043	0.021	0.055	0.041	0.049	0.037	0.050	0.040
14	0.112	0.040	0.045	0.023	0.042	0.021	0.053	0.040	0.047	0.035	0.047	0.038
15	0.112	0.040	0.043	0.022	0.041	0.020	0.051	0.038	0.045	0.034	0.045	0.036
16	0.112	0.040	0.041	0.020	0.040	0.020	0.049	0.037	0.044	0.033	0.044	0.036
17	0.112	0.040	0.039	0.020	0.039	0.020	0.048	0.036	0.043	0.032	0.044	0.036
18	0.112	0.040	0.037	0.019	0.039	0.019	0.047	0.035	0.042	0.032	0.044	0.036
19	0.112	0.040	0.036	0.018	0.038	0.019	0.045	0.034	0.042	0.032	0.044	0.036
20+	0.112	0.040	0.034	0.017	0.037	0.019	0.044	0.033	0.042	0.032	0.044	0.036

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

Table A-32. *Cs*[1] Values for Model Building Type C1 (Reinforced Concrete Moment Frame) for Site Class D[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.080	0.153	0.076	0.094	0.047	0.126	0.094	0.129	0.097	0.129	0.106
2	0.112	0.080	0.129	0.065	0.094	0.047	0.131	0.098	0.129	0.097	0.129	0.106
3	0.112	0.080	0.112	0.056	0.070	0.035	0.131	0.098	0.122	0.091	0.129	0.106
4	0.112	0.070	0.099	0.049	0.064	0.032	0.131	0.098	0.106	0.079	0.129	0.106
5	0.112	0.070	0.088	0.044	0.059	0.030	0.126	0.095	0.094	0.071	0.116	0.098
6	0.112	0.070	0.080	0.040	0.056	0.028	0.119	0.089	0.086	0.065	0.102	0.086
7	0.112	0.070	0.073	0.037	0.053	0.026	0.112	0.084	0.080	0.060	0.090	0.076
8	0.112	0.040	0.067	0.034	0.051	0.025	0.105	0.079	0.075	0.056	0.082	0.069
9	0.112	0.040	0.062	0.031	0.049	0.024	0.099	0.074	0.070	0.053	0.075	0.063
10	0.112	0.040	0.058	0.029	0.047	0.023	0.094	0.070	0.067	0.050	0.069	0.058
11	0.112	0.040	0.054	0.027	0.045	0.023	0.089	0.067	0.064	0.048	0.064	0.054
12	0.112	0.040	0.051	0.025	0.044	0.022	0.086	0.064	0.061	0.046	0.060	0.051
13	0.112	0.040	0.048	0.024	0.043	0.021	0.082	0.062	0.059	0.044	0.057	0.048
14	0.112	0.040	0.045	0.023	0.042	0.021	0.079	0.059	0.056	0.042	0.054	0.045
15	0.112	0.040	0.043	0.022	0.041	0.020	0.076	0.057	0.054	0.041	0.051	0.043
16	0.112	0.040	0.041	0.020	0.040	0.020	0.073	0.054	0.053	0.040	0.049	0.041
17	0.112	0.040	0.039	0.020	0.039	0.020	0.069	0.052	0.051	0.038	0.048	0.040
18	0.112	0.040	0.037	0.019	0.039	0.019	0.066	0.050	0.050	0.037	0.048	0.040
19	0.112	0.040	0.036	0.018	0.038	0.019	0.063	0.048	0.048	0.036	0.048	0.040
20+	0.112	0.040	0.034	0.017	0.037	0.019	0.060	0.045	0.047	0.035	0.048	0.040

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

Table A-33. *Cs*[1] Values for Model Building Type C1 (Reinforced Concrete Moment Frame) for Site Class E[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.224	0.080	0.153	0.076	0.094	0.047	0.120	0.090	0.129	0.097	0.106	0.106
2	0.224	0.080	0.129	0.065	0.094	0.047	0.127	0.095	0.129	0.097	0.106	0.106
3	0.224	0.080	0.112	0.056	0.070	0.035	0.131	0.098	0.129	0.097	0.106	0.106
4	0.224	0.070	0.099	0.049	0.064	0.032	0.122	0.091	0.129	0.097	0.106	0.106
5	0.224	0.070	0.088	0.044	0.059	0.030	0.113	0.085	0.118	0.088	0.106	0.106
6	0.224	0.070	0.080	0.040	0.056	0.028	0.107	0.080	0.108	0.081	0.106	0.106
7	0.224	0.070	0.073	0.037	0.053	0.026	0.101	0.076	0.100	0.075	0.106	0.106
8	0.224	0.040	0.067	0.034	0.051	0.025	0.097	0.073	0.093	0.070	0.106	0.106
9	0.224	0.040	0.062	0.031	0.049	0.024	0.094	0.070	0.088	0.066	0.106	0.098
10	0.224	0.040	0.058	0.029	0.047	0.023	0.090	0.068	0.083	0.063	0.104	0.091
11	0.224	0.040	0.054	0.027	0.045	0.023	0.087	0.065	0.080	0.060	0.097	0.085
12	0.224	0.040	0.051	0.025	0.044	0.022	0.084	0.063	0.076	0.057	0.091	0.079
13	0.224	0.040	0.048	0.024	0.043	0.021	0.082	0.061	0.073	0.055	0.085	0.075
14	0.224	0.040	0.045	0.023	0.042	0.021	0.079	0.059	0.071	0.053	0.081	0.071
15	0.224	0.040	0.043	0.022	0.041	0.020	0.077	0.057	0.068	0.051	0.077	0.067
16	0.224	0.040	0.041	0.020	0.040	0.020	0.074	0.056	0.066	0.049	0.073	0.064
17	0.224	0.040	0.039	0.020	0.039	0.020	0.072	0.054	0.064	0.048	0.070	0.061
18	0.224	0.040	0.037	0.019	0.039	0.019	0.069	0.052	0.062	0.047	0.067	0.058
19	0.224	0.040	0.036	0.018	0.038	0.019	0.067	0.050	0.061	0.045	0.064	0.056
20+	0.224	0.040	0.034	0.017	0.037	0.019	0.065	0.049	0.059	0.044	0.062	0.054

[1] Lateral Force Coefficient, *Cs*, in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

A.4.9 MODEL BUILDING TYPE C2

Table A-34. *Te* and *Cs*[1] Values for Model Building Type C2 (Reinforced Concrete Shear Walls) for Site Class B[2]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC*[3]	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	12	0.35	0.055	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
2	20	0.35	0.046	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
3	30	0.39	0.04	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.167
4	40	0.48	0.035	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.167
5	50	0.57	0.032	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.167
6	60	0.65	0.029	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.206	0.155
7	70	0.73	0.026	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.184	0.138
8	80	0.81	0.024	0.112	0.060	0.067	0.034	0.115	0.057	0.249	0.187	0.176	0.132	0.166	0.125
9	90	0.88	0.022	0.112	0.060	0.062	0.031	0.111	0.056	0.233	0.175	0.166	0.125	0.152	0.114
10	100	0.95	0.021	0.112	0.060	0.058	0.029	0.108	0.054	0.218	0.164	0.158	0.118	0.141	0.105
11	110	1.02	0.019	0.112	0.060	0.054	0.027	0.106	0.053	0.204	0.153	0.150	0.113	0.131	0.098
12	120	1.09	0.018	0.112	0.060	0.051	0.025	0.104	0.052	0.190	0.142	0.144	0.108	0.123	0.092
13	130	1.16	0.017	0.112	0.060	0.048	0.024	0.102	0.051	0.176	0.132	0.138	0.104	0.115	0.087
14	140	1.23	0.016	0.112	0.060	0.045	0.023	0.100	0.050	0.162	0.122	0.133	0.100	0.109	0.082
15	150	1.29	0.015	0.112	0.060	0.043	0.022	0.098	0.049	0.149	0.111	0.129	0.097	0.104	0.078
16	160	1.35	0.015	0.112	0.060	0.041	0.020	0.096	0.048	0.135	0.101	0.125	0.094	0.099	0.074
17	170	1.42	0.014	0.112	0.060	0.039	0.020	0.095	0.047	0.128	0.096	0.121	0.091	0.094	0.071
18	180	1.48	0.013	0.112	0.060	0.037	0.019	0.094	0.047	0.125	0.094	0.118	0.088	0.090	0.068
19	190	1.54	0.013	0.112	0.060	0.036	0.018	0.092	0.046	0.123	0.092	0.114	0.086	0.087	0.065
20+	200	1.6	0.012	0.112	0.060	0.034	0.017	0.091	0.046	0.120	0.090	0.112	0.084	0.084	0.063

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units
[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.
[3] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

Table A-35. *Cs*[1] Values for Model Building Type C2 (Reinforced Concrete Shear Walls) for Site Class C[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	
1	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.183
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.183
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.183
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.222	0.183
7	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.222	0.183
8	0.112	0.060	0.067	0.034	0.115	0.057	0.254	0.191	0.176	0.132	0.222	0.183
9	0.112	0.060	0.062	0.031	0.111	0.056	0.242	0.182	0.166	0.125	0.213	0.171
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.158	0.118	0.197	0.158
11	0.112	0.060	0.054	0.027	0.106	0.053	0.220	0.165	0.150	0.113	0.183	0.147
12	0.112	0.060	0.051	0.025	0.104	0.052	0.210	0.157	0.144	0.108	0.172	0.138
13	0.112	0.060	0.048	0.024	0.102	0.051	0.200	0.150	0.138	0.104	0.162	0.130
14	0.112	0.060	0.045	0.023	0.100	0.050	0.190	0.143	0.133	0.100	0.153	0.123
15	0.112	0.060	0.043	0.022	0.098	0.049	0.181	0.135	0.129	0.097	0.145	0.117
16	0.112	0.060	0.041	0.020	0.096	0.048	0.171	0.128	0.125	0.094	0.138	0.111
17	0.112	0.060	0.039	0.020	0.095	0.047	0.162	0.121	0.121	0.091	0.132	0.106
18	0.112	0.060	0.037	0.019	0.094	0.047	0.153	0.115	0.118	0.088	0.127	0.102
19	0.112	0.060	0.036	0.018	0.092	0.046	0.144	0.108	0.114	0.086	0.122	0.098
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.135	0.101	0.112	0.084	0.117	0.094

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

Table A-36. *Cs*[1] Values for Model Building Type C2 (Reinforced Concrete Shear Walls) for Site Class D[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.100	0.153	0.076	0.186	0.093	0.253	0.189	0.256	0.192	0.244	0.200
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.244	0.200
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.244	0.200
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.244	0.200
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.256	0.192	0.244	0.200
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.244	0.183	0.244	0.200
7	0.112	0.070	0.073	0.037	0.119	0.059	0.254	0.190	0.226	0.170	0.244	0.200
8	0.112	0.060	0.067	0.034	0.115	0.057	0.245	0.184	0.212	0.159	0.244	0.200
9	0.112	0.060	0.062	0.031	0.111	0.056	0.238	0.178	0.200	0.150	0.243	0.200
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.189	0.142	0.225	0.190
11	0.112	0.060	0.054	0.027	0.106	0.053	0.224	0.168	0.181	0.135	0.209	0.177
12	0.112	0.060	0.051	0.025	0.104	0.052	0.218	0.164	0.173	0.130	0.196	0.165
13	0.112	0.060	0.048	0.024	0.102	0.051	0.212	0.159	0.166	0.125	0.185	0.156
14	0.112	0.060	0.045	0.023	0.100	0.050	0.206	0.155	0.160	0.120	0.175	0.147
15	0.112	0.060	0.043	0.022	0.098	0.049	0.201	0.151	0.155	0.116	0.166	0.140
16	0.112	0.060	0.041	0.020	0.096	0.048	0.196	0.147	0.150	0.112	0.158	0.133
17	0.112	0.060	0.039	0.020	0.095	0.047	0.192	0.144	0.145	0.109	0.151	0.127
18	0.112	0.060	0.037	0.019	0.094	0.047	0.188	0.141	0.141	0.106	0.145	0.122
19	0.112	0.060	0.036	0.018	0.092	0.046	0.184	0.138	0.137	0.103	0.139	0.117
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.181	0.135	0.134	0.100	0.134	0.113

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

Table A-37. *Cs*[1] Values for Model Building Type C2 (Reinforced Concrete Shear Walls) for Site Class E[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.224	0.100	0.153	0.076	0.186	0.093	0.240	0.180	0.256	0.192	0.200	0.200
2	0.224	0.100	0.129	0.065	0.186	0.093	0.250	0.187	0.256	0.192	0.200	0.200
3	0.224	0.100	0.112	0.056	0.147	0.073	0.258	0.194	0.256	0.192	0.200	0.200
4	0.224	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.200	0.200
5	0.224	0.070	0.088	0.044	0.129	0.064	0.247	0.185	0.256	0.192	0.200	0.200
6	0.224	0.070	0.080	0.040	0.123	0.062	0.236	0.177	0.256	0.192	0.200	0.200
7	0.224	0.070	0.073	0.037	0.119	0.059	0.227	0.170	0.256	0.192	0.200	0.200
8	0.224	0.060	0.067	0.034	0.115	0.057	0.219	0.165	0.256	0.192	0.200	0.200
9	0.224	0.060	0.062	0.031	0.111	0.056	0.213	0.160	0.250	0.187	0.200	0.200
10	0.224	0.060	0.058	0.029	0.108	0.054	0.208	0.156	0.237	0.178	0.200	0.200
11	0.224	0.060	0.054	0.027	0.106	0.053	0.203	0.153	0.226	0.169	0.200	0.200
12	0.224	0.060	0.051	0.025	0.104	0.052	0.199	0.149	0.216	0.162	0.200	0.200
13	0.224	0.060	0.048	0.024	0.102	0.051	0.195	0.147	0.208	0.156	0.200	0.200
14	0.224	0.060	0.045	0.023	0.100	0.050	0.192	0.144	0.200	0.150	0.200	0.200
15	0.224	0.060	0.043	0.022	0.098	0.049	0.189	0.142	0.193	0.145	0.200	0.200
16	0.224	0.060	0.041	0.020	0.096	0.048	0.186	0.139	0.187	0.140	0.200	0.200
17	0.224	0.060	0.039	0.020	0.095	0.047	0.183	0.137	0.182	0.136	0.200	0.198
18	0.224	0.060	0.037	0.019	0.094	0.047	0.180	0.135	0.176	0.132	0.200	0.190
19	0.224	0.060	0.036	0.018	0.092	0.046	0.178	0.133	0.172	0.129	0.200	0.182
20+	0.224	0.060	0.034	0.017	0.091	0.046	0.175	0.132	0.167	0.126	0.200	0.175

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

A.4.10 MODEL BUILDING TYPE C3

Table A-38. *Te* and *Cs* Values for Model Building Type C3 (Concrete Frame with URM Infill Shear Walls)[1]

No. of Stories	*Hn*	*Te*	*Cs*[2]
1	12	0.35	0.055
2	20	0.35	0.046
3	30	0.39	0.04
4	40	0.48	0.035
5	50	0.57	0.032
6	60	0.65	0.029
7	70	0.73	0.026
8	80	0.81	0.024
9	90	0.88	0.022
10	100	0.95	0.021
11	110	1.02	0.019
12	120	1.09	0.018
13	130	1.16	0.017
14	140	1.23	0.016
15	150	1.29	0.015
16	160	1.35	0.015
17	170	1.42	0.014
18	180	1.48	0.013
19	190	1.54	0.013
20+	200	1.6	0.012

[1] All of these buildings are pre-Code, as URM was prohibited by all editions of the UBC for seismic shear walls. All values come from HAZUS-OSHPD.

[2] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

A.4.11 MODEL BUILDING TYPE PC1

Table A-39. *Te* and *Cs*[1] Values for Model Building Type PC1 (Precast Concrete Tilt-up Walls) for Site Class B[2]

No. of Stories	*Hn*	*Te*[3]	*Cs, Pre-UBC*[4]	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	15	0.35	0.055	—	—	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
2	25	0.39	0.046	—	—	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
3[5]	35	0.5	0.04	—	—	0.112	0.056	0.132	0.066	0.261	0.196	0.235	0.176	0.222	0.167

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.

[3] Roof diaphragm spans typically control actual period.

[4] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

[5] There are few 3-story tilt-ups; tilt-up construction began in the 1950s.

Table A-40. *Cs*[1] Values for Model Building Type PC1 (Precast Concrete Tilt-up Walls) for Site Class C[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	—	—	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
2	—	—	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
3[3]	—	—	0.112	0.056	0.132	0.066	0.261	0.196	0.235	0.176	0.222	0.183

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

[3] There are few 3-story tilt-ups; tilt-up construction began in the 1950s.

Table A-41. *Cs*[1] Values for Model Building Type PC1 (Precast Concrete Tilt-up Walls) for Site Class D[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	—	—	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.244	0.200
2	—	—	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.244	0.200
3[3]	—	—	0.112	0.056	0.132	0.066	0.261	0.196	0.256	0.192	0.244	0.200

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

[3] There are few 3-story tilt-ups; tilt-up construction began in the 1950s.

Table A-42. *Cs*[1] Values for Model Building Type PC1 (Precast Concrete Tilt-up Walls) for Site Class E[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	—	—	0.153	0.076	0.186	0.093	0.254	0.191	0.256	0.192	0.200	0.200
2	—	—	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.200	0.200
3[3]	—	—	0.112	0.056	0.132	0.066	0.254	0.190	0.256	0.192	0.200	0.200

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

[3] There are few 3-story tilt-ups; tilt-up construction began in the 1950s.

A.4.12 MODEL BUILDING TYPE PC2

Table A-43. *Te* and *Cs*[1] Values for Model Building Type PC2 (Precast Concrete Shear Walls) for Site Class B[2]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC*[3]	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	12	0.35	0.055	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
2	20	0.35	0.046	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
3	30	0.39	0.04	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.167
4	40	0.48	0.035	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.167
5	50	0.57	0.032	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.167
6	60	0.65	0.029	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.206	0.155
7	70	0.73	0.026	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.184	0.138
8	80	0.81	0.024	0.112	0.060	0.067	0.034	0.115	0.057	0.249	0.187	0.176	0.132	0.166	0.125
9	90	0.88	0.022	0.112	0.060	0.062	0.031	0.111	0.056	0.233	0.175	0.166	0.125	0.152	0.114
10	100	0.95	0.021	0.112	0.060	0.058	0.029	0.108	0.054	0.218	0.164	0.158	0.118	0.141	0.105
11	110	1.02	0.019	0.112	0.060	0.054	0.027	0.106	0.053	0.204	0.153	0.150	0.113	0.131	0.098
12	120	1.09	0.018	0.112	0.060	0.051	0.025	0.104	0.052	0.190	0.142	0.144	0.108	0.123	0.092
13	130	1.16	0.017	0.112	0.060	0.048	0.024	0.102	0.051	0.176	0.132	0.138	0.104	0.115	0.087
14	140	1.23	0.016	0.112	0.060	0.045	0.023	0.100	0.050	0.162	0.122	0.133	0.100	0.109	0.082
15	150	1.29	0.015	0.112	0.060	0.043	0.022	0.098	0.049	0.149	0.111	0.129	0.097	0.104	0.078
16	160	1.35	0.015	0.112	0.060	0.041	0.020	0.096	0.048	0.135	0.101	0.125	0.094	0.099	0.074
17	170	1.42	0.014	0.112	0.060	0.039	0.020	0.095	0.047	0.128	0.096	0.121	0.091	0.094	0.071
18	180	1.48	0.013	0.112	0.060	0.037	0.019	0.094	0.047	0.125	0.094	0.118	0.088	0.090	0.068
19	190	1.54	0.013	0.112	0.060	0.036	0.018	0.092	0.046	0.123	0.092	0.114	0.086	0.087	0.065
20+	200	1.6	0.012	0.112	0.060	0.034	0.017	0.091	0.046	0.120	0.090	0.112	0.084	0.084	0.063

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units
[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.
[3] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

Table A-44. *Cs*[1] Values for Model Building Type PC2 (Precast Concrete Shear Walls) for Site Class C[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	
1	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.183
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.183
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.183
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.222	0.183
7	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.222	0.183
8	0.112	0.060	0.067	0.034	0.115	0.057	0.254	0.191	0.176	0.132	0.222	0.183
9	0.112	0.060	0.062	0.031	0.111	0.056	0.242	0.182	0.166	0.125	0.213	0.171
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.158	0.118	0.197	0.158
11	0.112	0.060	0.054	0.027	0.106	0.053	0.220	0.165	0.150	0.113	0.183	0.147
12	0.112	0.060	0.051	0.025	0.104	0.052	0.210	0.157	0.144	0.108	0.172	0.138
13	0.112	0.060	0.048	0.024	0.102	0.051	0.200	0.150	0.138	0.104	0.162	0.130
14	0.112	0.060	0.045	0.023	0.100	0.050	0.190	0.143	0.133	0.100	0.153	0.123
15	0.112	0.060	0.043	0.022	0.098	0.049	0.181	0.135	0.129	0.097	0.145	0.117
16	0.112	0.060	0.041	0.020	0.096	0.048	0.171	0.128	0.125	0.094	0.138	0.111
17	0.112	0.060	0.039	0.020	0.095	0.047	0.162	0.121	0.121	0.091	0.132	0.106
18	0.112	0.060	0.037	0.019	0.094	0.047	0.153	0.115	0.118	0.088	0.127	0.102
19	0.112	0.060	0.036	0.018	0.092	0.046	0.144	0.108	0.114	0.086	0.122	0.098
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.135	0.101	0.112	0.084	0.117	0.094

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

Table A-45. *Cs*[1] Values for Model Building Type PC2 (Precast Concrete Shear Walls) for Site Class D[2]

No. of Stories	UBC 1935-1946, Zone 3	UBC 1935-1946, Zone 2	UBC 1949-1958, Zone 3	UBC 1949-1958, Zone 2	UBC 1961-1973, Zone 3	UBC 1961-1973, Zone 2	UBC 1976-1985, Zone 4	UBC 1976-1985, Zone 3	UBC 1988-1994, Zone 4	UBC 1988-1994, Zone 3	UBC 1997, Zone 4	UBC 1997, Zone 3
1	0.112	0.100	0.153	0.076	0.186	0.093	0.253	0.189	0.256	0.192	0.244	0.200
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.244	0.200
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.244	0.200
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.244	0.200
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.256	0.192	0.244	0.200
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.244	0.183	0.244	0.200
7	0.112	0.070	0.073	0.037	0.119	0.059	0.254	0.190	0.226	0.170	0.244	0.200
8	0.112	0.060	0.067	0.034	0.115	0.057	0.245	0.184	0.212	0.159	0.244	0.200
9	0.112	0.060	0.062	0.031	0.111	0.056	0.238	0.178	0.200	0.150	0.243	0.200
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.189	0.142	0.225	0.190
11	0.112	0.060	0.054	0.027	0.106	0.053	0.224	0.168	0.181	0.135	0.209	0.177
12	0.112	0.060	0.051	0.025	0.104	0.052	0.218	0.164	0.173	0.130	0.196	0.165
13	0.112	0.060	0.048	0.024	0.102	0.051	0.212	0.159	0.166	0.125	0.185	0.156
14	0.112	0.060	0.045	0.023	0.100	0.050	0.206	0.155	0.160	0.120	0.175	0.147
15	0.112	0.060	0.043	0.022	0.098	0.049	0.201	0.151	0.155	0.116	0.166	0.140
16	0.112	0.060	0.041	0.020	0.096	0.048	0.196	0.147	0.150	0.112	0.158	0.133
17	0.112	0.060	0.039	0.020	0.095	0.047	0.192	0.144	0.145	0.109	0.151	0.127
18	0.112	0.060	0.037	0.019	0.094	0.047	0.188	0.141	0.141	0.106	0.145	0.122
19	0.112	0.060	0.036	0.018	0.092	0.046	0.184	0.138	0.137	0.103	0.139	0.117
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.181	0.135	0.134	0.100	0.134	0.113

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

Table A-46. *Cs*[1] Values for Model Building Type PC2 (Precast Concrete Shear Walls) for Site Class E[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.224	0.100	0.153	0.076	0.186	0.093	0.240	0.180	0.256	0.192	0.200	0.200
2	0.224	0.100	0.129	0.065	0.186	0.093	0.250	0.187	0.256	0.192	0.200	0.200
3	0.224	0.100	0.112	0.056	0.147	0.073	0.258	0.194	0.256	0.192	0.200	0.200
4	0.224	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.200	0.200
5	0.224	0.070	0.088	0.044	0.129	0.064	0.247	0.185	0.256	0.192	0.200	0.200
6	0.224	0.070	0.080	0.040	0.123	0.062	0.236	0.177	0.256	0.192	0.200	0.200
7	0.224	0.070	0.073	0.037	0.119	0.059	0.227	0.170	0.256	0.192	0.200	0.200
8	0.224	0.060	0.067	0.034	0.115	0.057	0.219	0.165	0.256	0.192	0.200	0.200
9	0.224	0.060	0.062	0.031	0.111	0.056	0.213	0.160	0.250	0.187	0.200	0.200
10	0.224	0.060	0.058	0.029	0.108	0.054	0.208	0.156	0.237	0.178	0.200	0.200
11	0.224	0.060	0.054	0.027	0.106	0.053	0.203	0.153	0.226	0.169	0.200	0.200
12	0.224	0.060	0.051	0.025	0.104	0.052	0.199	0.149	0.216	0.162	0.200	0.200
13	0.224	0.060	0.048	0.024	0.102	0.051	0.195	0.147	0.208	0.156	0.200	0.200
14	0.224	0.060	0.045	0.023	0.100	0.050	0.192	0.144	0.200	0.150	0.200	0.200
15	0.224	0.060	0.043	0.022	0.098	0.049	0.189	0.142	0.193	0.145	0.200	0.200
16	0.224	0.060	0.041	0.020	0.096	0.048	0.186	0.139	0.187	0.140	0.200	0.200
17	0.224	0.060	0.039	0.020	0.095	0.047	0.183	0.137	0.182	0.136	0.200	0.198
18	0.224	0.060	0.037	0.019	0.094	0.047	0.180	0.135	0.176	0.132	0.200	0.190
19	0.224	0.060	0.036	0.018	0.092	0.046	0.178	0.133	0.172	0.129	0.200	0.182
20+	0.224	0.060	0.034	0.017	0.091	0.046	0.175	0.132	0.167	0.126	0.200	0.175

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units

[2] Values are from the UBC editions indicated.

A.4.13 MODEL BUILDING TYPE RM

Table A-47. *Te* and *Cs*[1] Values for Model Building Type RM (Reinforced Masonry Shear Walls) for Site Class B[2]

No. of Stories	*Hn*	*Te*	*Cs, Pre-UBC*[3]	*Cs, UBC 1935-1946, Zone 3*	*Cs, UBC 1935-1946, Zone 2*	*Cs, UBC 1949-1958, Zone 3*	*Cs, UBC 1949-1958, Zone 2*	*Cs, UBC 1961-1973, Zone 3*	*Cs, UBC 1961-1973, Zone 2*	*Cs, UBC 1976-1985, Zone 4*	*Cs, UBC 1976-1985, Zone 3*	*Cs, UBC 1988-1994, Zone 4*	*Cs, UBC 1988-1994, Zone 3*	*Cs, UBC 1997, Zone 4*	*Cs, UBC 1997, Zone 3*
1	12	0.35	0.055	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
2	20	0.35	0.046	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.167
3	30	0.39	0.04	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.167
4	40	0.48	0.035	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.167
5	50	0.57	0.032	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.167
6	60	0.65	0.029	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.206	0.155
7	70	0.73	0.026	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.184	0.138
8	80	0.81	0.024	0.112	0.060	0.067	0.034	0.115	0.057	0.249	0.187	0.176	0.132	0.166	0.125
9	90	0.88	0.022	0.112	0.060	0.062	0.031	0.111	0.056	0.233	0.175	0.166	0.125	0.152	0.114
10	100	0.95	0.021	0.112	0.060	0.058	0.029	0.108	0.054	0.218	0.164	0.158	0.118	0.141	0.105
11	110	1.02	0.019	0.112	0.060	0.054	0.027	0.106	0.053	0.204	0.153	0.150	0.113	0.131	0.098
12	120	1.09	0.018	0.112	0.060	0.051	0.025	0.104	0.052	0.190	0.142	0.144	0.108	0.123	0.092
13	130	1.16	0.017	0.112	0.060	0.048	0.024	0.102	0.051	0.176	0.132	0.138	0.104	0.115	0.087
14	140	1.23	0.016	0.112	0.060	0.045	0.023	0.100	0.050	0.162	0.122	0.133	0.100	0.109	0.082
15	150	1.29	0.015	0.112	0.060	0.043	0.022	0.098	0.049	0.149	0.111	0.129	0.097	0.104	0.078
16	160	1.35	0.015	0.112	0.060	0.041	0.020	0.096	0.048	0.135	0.101	0.125	0.094	0.099	0.074
17	170	1.42	0.014	0.112	0.060	0.039	0.020	0.095	0.047	0.128	0.096	0.121	0.091	0.094	0.071
18	180	1.48	0.013	0.112	0.060	0.037	0.019	0.094	0.047	0.125	0.094	0.118	0.088	0.090	0.068
19	190	1.54	0.013	0.112	0.060	0.036	0.018	0.092	0.046	0.123	0.092	0.114	0.086	0.087	0.065
20+	200	1.6	0.012	0.112	0.060	0.034	0.017	0.091	0.046	0.120	0.090	0.112	0.084	0.084	0.063

[1] Lateral Force Coefficient, *Cs* in Ultimate Strength Units
[2] Values in Hn, Te, and Pre-UBC Cs columns are from HAZUS-OSHPD. Remaining values are from the UBC editions indicated.
[3] Cs for Pre-UBC case taken from Zone 3, Pre-1961 value for URM in Table 16-2a (CAC, 2022).

Table A-48. *Cs*[1] Values for Model Building Type RM (Reinforced Masonry Shear Walls) for Site Class C[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.112	0.100	0.153	0.076	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.222	0.183
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.222	0.183
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.250	0.187	0.222	0.183
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.223	0.167	0.222	0.183
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.204	0.153	0.222	0.183
7	0.112	0.070	0.073	0.037	0.119	0.059	0.261	0.196	0.189	0.141	0.222	0.183
8	0.112	0.060	0.067	0.034	0.115	0.057	0.254	0.191	0.176	0.132	0.222	0.183
9	0.112	0.060	0.062	0.031	0.111	0.056	0.242	0.182	0.166	0.125	0.213	0.171
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.158	0.118	0.197	0.158
11	0.112	0.060	0.054	0.027	0.106	0.053	0.220	0.165	0.150	0.113	0.183	0.147
12	0.112	0.060	0.051	0.025	0.104	0.052	0.210	0.157	0.144	0.108	0.172	0.138
13	0.112	0.060	0.048	0.024	0.102	0.051	0.200	0.150	0.138	0.104	0.162	0.130
14	0.112	0.060	0.045	0.023	0.100	0.050	0.190	0.143	0.133	0.100	0.153	0.123
15	0.112	0.060	0.043	0.022	0.098	0.049	0.181	0.135	0.129	0.097	0.145	0.117
16	0.112	0.060	0.041	0.020	0.096	0.048	0.171	0.128	0.125	0.094	0.138	0.111
17	0.112	0.060	0.039	0.020	0.095	0.047	0.162	0.121	0.121	0.091	0.132	0.106
18	0.112	0.060	0.037	0.019	0.094	0.047	0.153	0.115	0.118	0.088	0.127	0.102
19	0.112	0.060	0.036	0.018	0.092	0.046	0.144	0.108	0.114	0.086	0.122	0.098
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.135	0.101	0.112	0.084	0.117	0.094

[1] Lateral Force Coefficient, Cs in Ultimate Strength Units.

[2] Values are from the UBC editions indicated.

Table A-49. *Cs*[1] Values for Model Building Type RM (Reinforced Masonry Shear Walls) for Site Class D[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.112	0.100	0.153	0.076	0.186	0.093	0.253	0.189	0.256	0.192	0.244	0.200
2	0.112	0.100	0.129	0.065	0.186	0.093	0.261	0.196	0.256	0.192	0.244	0.200
3	0.112	0.100	0.112	0.056	0.147	0.073	0.261	0.196	0.256	0.192	0.244	0.200
4	0.112	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.244	0.200
5	0.112	0.070	0.088	0.044	0.129	0.064	0.261	0.196	0.256	0.192	0.244	0.200
6	0.112	0.070	0.080	0.040	0.123	0.062	0.261	0.196	0.244	0.183	0.244	0.200
7	0.112	0.070	0.073	0.037	0.119	0.059	0.254	0.190	0.226	0.170	0.244	0.200
8	0.112	0.060	0.067	0.034	0.115	0.057	0.245	0.184	0.212	0.159	0.244	0.200
9	0.112	0.060	0.062	0.031	0.111	0.056	0.238	0.178	0.200	0.150	0.243	0.200
10	0.112	0.060	0.058	0.029	0.108	0.054	0.231	0.173	0.189	0.142	0.225	0.190
11	0.112	0.060	0.054	0.027	0.106	0.053	0.224	0.168	0.181	0.135	0.209	0.177
12	0.112	0.060	0.051	0.025	0.104	0.052	0.218	0.164	0.173	0.130	0.196	0.165
13	0.112	0.060	0.048	0.024	0.102	0.051	0.212	0.159	0.166	0.125	0.185	0.156
14	0.112	0.060	0.045	0.023	0.100	0.050	0.206	0.155	0.160	0.120	0.175	0.147
15	0.112	0.060	0.043	0.022	0.098	0.049	0.201	0.151	0.155	0.116	0.166	0.140
16	0.112	0.060	0.041	0.020	0.096	0.048	0.196	0.147	0.150	0.112	0.158	0.133
17	0.112	0.060	0.039	0.020	0.095	0.047	0.192	0.144	0.145	0.109	0.151	0.127
18	0.112	0.060	0.037	0.019	0.094	0.047	0.188	0.141	0.141	0.106	0.145	0.122
19	0.112	0.060	0.036	0.018	0.092	0.046	0.184	0.138	0.137	0.103	0.139	0.117
20+	0.112	0.060	0.034	0.017	0.091	0.046	0.181	0.135	0.134	0.100	0.134	0.113

[1] Lateral Force Coefficient, Cs in Ultimate Strength Units.

[2] Values are from the UBC editions indicated.

Table A-50. *Cs*[1] Values for Model Building Type RM (Reinforced Masonry Shear Walls) for Site Class E[2]

No. of Stories	*UBC 1935-1946, Zone 3*	*UBC 1935-1946, Zone 2*	*UBC 1949-1958, Zone 3*	*UBC 1949-1958, Zone 2*	*UBC 1961-1973, Zone 3*	*UBC 1961-1973, Zone 2*	*UBC 1976-1985, Zone 4*	*UBC 1976-1985, Zone 3*	*UBC 1988-1994, Zone 4*	*UBC 1988-1994, Zone 3*	*UBC 1997, Zone 4*	*UBC 1997, Zone 3*
1	0.224	0.100	0.153	0.076	0.186	0.093	0.240	0.180	0.256	0.192	0.200	0.200
2	0.224	0.100	0.129	0.065	0.186	0.093	0.250	0.187	0.256	0.192	0.200	0.200
3	0.224	0.100	0.112	0.056	0.147	0.073	0.258	0.194	0.256	0.192	0.200	0.200
4	0.224	0.070	0.099	0.049	0.136	0.068	0.261	0.196	0.256	0.192	0.200	0.200
5	0.224	0.070	0.088	0.044	0.129	0.064	0.247	0.185	0.256	0.192	0.200	0.200
6	0.224	0.070	0.080	0.040	0.123	0.062	0.236	0.177	0.256	0.192	0.200	0.200
7	0.224	0.070	0.073	0.037	0.119	0.059	0.227	0.170	0.256	0.192	0.200	0.200
8	0.224	0.060	0.067	0.034	0.115	0.057	0.219	0.165	0.256	0.192	0.200	0.200
9	0.224	0.060	0.062	0.031	0.111	0.056	0.213	0.160	0.250	0.187	0.200	0.200
10	0.224	0.060	0.058	0.029	0.108	0.054	0.208	0.156	0.237	0.178	0.200	0.200
11	0.224	0.060	0.054	0.027	0.106	0.053	0.203	0.153	0.226	0.169	0.200	0.200
12	0.224	0.060	0.051	0.025	0.104	0.052	0.199	0.149	0.216	0.162	0.200	0.200
13	0.224	0.060	0.048	0.024	0.102	0.051	0.195	0.147	0.208	0.156	0.200	0.200
14	0.224	0.060	0.045	0.023	0.100	0.050	0.192	0.144	0.200	0.150	0.200	0.200
15	0.224	0.060	0.043	0.022	0.098	0.049	0.189	0.142	0.193	0.145	0.200	0.200
16	0.224	0.060	0.041	0.020	0.096	0.048	0.186	0.139	0.187	0.140	0.200	0.200
17	0.224	0.060	0.039	0.020	0.095	0.047	0.183	0.137	0.182	0.136	0.200	0.198
18	0.224	0.060	0.037	0.019	0.094	0.047	0.180	0.135	0.176	0.132	0.200	0.190
19	0.224	0.060	0.036	0.018	0.092	0.046	0.178	0.133	0.172	0.129	0.200	0.182
20+	0.224	0.060	0.034	0.017	0.091	0.046	0.175	0.132	0.167	0.126	0.200	0.175

[1] Lateral Force Coefficient, Cs in Ultimate Strength Units.

[2] Values are from the UBC editions indicated.

A.4.14 MODEL BUILDING TYPE URM

Table A-51. *Te* and *Cs* Values for Model Building Type URM (Unreinforced Masonry)[1]

No. of Stories[2]	*Hn*	*Te*	*Cs*[3]
1	12	0.35	0.109
2	20	0.35	0.092
3	30	0.39	0.08
4	40	0.48	0.071
5	50	0.57	0.063
6	60	0.65	0.057
7	70	0.73	0.052
8	80	0.81	0.048
9	90	0.88	0.044
10	100	0.95	0.041
11	110	1.02	0.039
12	120	1.09	0.036
13	130	1.16	0.034
14	140	1.23	0.032
15	150	1.29	0.031
16	160	1.35	0.029
17	170	1.42	0.028
18	180	1.48	0.027
19	190	1.54	0.026
20+	200	1.6	0.024

[1] All URMs are essentially "pre-Code" as they are not permitted in seismic design codes. Also, UBC Zones 3 and 4 are irrelevant to URM. All values are from HAZUS-OSHPD.
[2] URM Bearing Wall buildings are typically shorter than 9 stories. Taller buildings have a concrete or steel gravity frame, which may be better modeled as Model Building Types S5 or C3.
[3] Lateral Force Coefficient, *Cs* in Ultimate Strength Units. Post-retrofit Cs should assume a 10% improvement from pre-retrofit conditions.

Appendix B: Vulnerability Parameter Data Dictionary

Table B-1 is the data dictionary of the vulnerability parameters, including the source of each of their updated default values. Tables B-2 through B-18 contain the values for the variables listed in Table B-1, which were obtained from Appendix H to Chapter 6 HAZUS AEBM Regulations (CAC, 2022).

Table B-1. Vulnerability Parameters Data Dictionary

Parameter	***Symbol***	***Units***	***Source of Value***
Elastic Period	*Te*	seconds	Tables A1 – A51 in Appendix A list values for *Te* and *Cs* based on the number of stories, Model Building Type, UBC edition, and Site Class.
Elastic Damping	$\boldsymbol{\beta}_E$	percent of critical damping	Table B-9 lists values for Elastic Damping, $\boldsymbol{\beta}_E$, based on the Model Building Type.
Design "Lateral Force Coefficient"	*Cs*	fraction of seismic weight, in Load and Resistance Factor Design (LRFD) units	Tables A1 – A51 in Appendix A list values for *Te* and *Cs* based on the number of stories, Model Building Type, UBC edition, and Site Class.
Structural Complete Damage Median	STR_C	Drift Ratio, dimensionless	Table B-13 lists values based on Structural Type, Collapse Performance Category, and design era (pre-1961, post-1961). PC1 has a pre-1975, post-1975 split.
Nonstructural Acceleration-Sensitive Complete Damage Median	NSA_C	[g]	Tables 7 and 8 in section 3.5 of this methodology report list these values.
Nonstructural Drift-Sensitive Complete Damage Median	NSD_C	Drift Ratio, dimensionless	Table 9 in section 3.5 of this methodology report lists these values. Tables 7 and 8 in section 3.5 of this methodology report list these values.
Kappa – Degradation Factor	Kappa *K*	nondimensional	Figure B-5 lists pre-retrofit Kappa values by building type, original UBC design code edition, and Zone. IBC equivalents are also given.
Collapse Performance Category (CPC)	Baseline, Sub-Base, Ultra Sub-Base	NA	Values are calculated using a modified and abridged set of ASCE 41 statements as described in section 3.4 of this methodology report, titled Accounting for Structural Deficiencies. The "Collapse Prevention" set is supplemented by statements specific to the Structural Type.

Parameter	*Symbol*	*Units*	*Source of Value*
Nonstructural Life-Safety Performance	Poor, Fair, Good	NA	Values are calculated using a modified and abridged set of ASCE 41 statements for nonstructural elements as described in section 3.4 of this methodology report, titled Accounting for Structural Deficiencies.
Alpha1 – Modal weight factor	$\alpha 1$	nondimensional	Figure B-1 lists values for each structural system as a function of height.
Alpha2 – Modal height factor	$\alpha 2$	nondimensional	Figure B-2 lists values for each structural system as a function of height.
Alpha3 – Modal shape factor	$\alpha 3$	nondimensional	Figure B-14 lists values as a function of height and Collapse Performance Category.
Gamma	γ	nondimensional	Figure B-4 lists values as a function of height.
Lambda	λ	nondimensional	Figures B-5 through B-7 list values as a function of height and structural system and Collapse Performance Category.
Mu, Ductility Factor	μ	nondimensional	Figure B-8 lists values as a function of height.
Collapse Factor	P(Col:DS_5)	nondimensional	Figures B-16 through B-18 list values for each structural system, for each Collapse Performance Category.

Table B-2. Alpha 1 (α1) Modal Weight Factor by Model Building Type[1]

No. of Stories	*S1 and C1*	*W1, W2, S2, S3, S4, C2, C3, PC2, RM1, and RM2*	*PC1 and URM*	*MH*
1	0.75	0.80	0 75	1.00
2	0.75	0.80	0.75	—
3	0.75	0.80	0.75	—
4	0.75	0.80	—	—
5	0.75	0.80	—	—
6	0.73	0.79	—	—
7	0.71	0.78	—	—
8	0.69	0.77	—	—
9	0.67	0.76	—	—
10	0.65	0.75	—	—
11	0.65	0.75	—	—
12	0.65	0.75	—	—
13	0.65	0.75	—	—
14	0.65	0.75	—	—
> =15	0.65	0.75	—	—

[1] Adapted from Table A6-4 - Alpha 1 Modal Weight Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-3. Alpha 2 ($\alpha 2$) Modal Weight Factor by Model Building Type[1]

No. of Stories	*MH*	*All Systems Except MH*
1	1.00	0.75
2	–	0.75
3	–	0.75
4	–	0.75
5	–	0.75
6	–	0.72
7	–	0.69
8	–	0.66
9	–	0.63
10	–	0.60
11	–	0.60
12	–	0.60
13	–	0.60
14	–	0.60
> =15	–	0.60

[1] Adapted from Table A6-4 - Alpha 2 Modal Height Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-4. Gamma Factor (γ) by Number of Stories[1]

No. of Stories	*Gamma Factor*
1	2.70
2	2.50
3	2.25
4	2.00
5	1.88
6	1.80
7	1.75
8	1.71
9	1.69
10	1.67
11	1.65
12	1.65
13	1.65
14	1.65
>=15	1.65

[1] Adapted from Table A6-5 Lambda Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-5. Lambda Factor (λ) for Baseline Performance, by Model Building Type[1]

No. of Stories	*W1, S1, C1*	*W2, C2*	*S4, C3*	*Other Model Building Type*	*PC1, URM*
1	2	2	1.83	1.67	1.33
2	2	2	1.83	1.67	1.33
3	2	2	1.83	1.67	1.33
4	2	2	1.83	1.67	1.33
5	2	2	1.83	1.67	1.33
6	2	2	1.83	1.67	1.33
7	2	2	1.83	1.67	1.33
8	2	2	1.83	1.67	1.33
9	2	2	1.83	1.67	1.33
10	2	2	1.83	1.67	1.33
11	2	2	1.83	1.67	1.33
12	2	2	1.83	1.67	1.33
13	2	2	1.83	1.67	1.33
14	2	2	1.83	1.67	1.33
>=15	2	2	1.83	1.67	1.33

[1] Adapted from Table A6-5 Lambda Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-6. Lambda Factor (λ) for Sub-Base Performance, by Model Building Type[1]

No. of Stories	*W1, S1, C1*	*W2, C2*	*S4, C3*	*Other Model Building Type*	*PC1, URM*
1	1.75	1.75	1.63	1.50	1.25
2	1.75	1.75	1.63	1.50	1.25
3	1.75	1.75	1.63	1.50	1.25
4	1.75	1.75	1.63	1.50	1.25
5	1.75	1.75	1.63	1.50	1.25
6	1.75	1.75	1.63	1.50	1.25
7	1.75	1.75	1.63	1.50	1.25
8	1.75	1.75	1.63	1.50	1.25
9	1.75	1.75	1.63	1.50	1.25
10	1.75	1.75	1.63	1.50	1.25
11	1.75	1.75	1.63	1.50	1.25
12	1.75	1.75	1.63	1.50	1.25
13	1.75	1.75	1.63	1.50	1.25
14	1.75	1.75	1.63	1.50	1.25
>=15	1.75	1.75	1.63	1.50	1.25

[1] Adapted from Table A6-5 Lambda Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-7. Lambda Factor (λ) for Ultra Sub-Base Performance, by Model Building Type[1]

No. of Stories	*W1, S1, C1*	*W2, C2*	*S4, C3*	*Other Model Building Type*	*PC1, URM*
1	1.50	1.50	1.42	1.33	1.17
2	1.50	1.50	1.42	1.33	1.17
3	1.50	1.50	1.42	1.33	1.17
4	1.50	1.50	1.42	1.33	1.17
5	1.50	1.50	1.42	1.33	1.17
6	1.50	1.50	1.42	1.33	1.17
7	1.50	1.50	L42	1.33	1.17
8	1.50	1.50	1.42	1.33	1.17
9	1.50	1.50	1.42	1.33	1.17
10	1.50	1.50	1.42	1.33	1.17
11	1.50	1.50	1.42	1.33	1.17
12	1.50	1.50	1.42	1.33	1.17
13	1.50	1.50	1.42	1.33	1.17
14	1.50	1.50	1.42	1.33	1.17
>=15	1.50	1.50	1.42	1.33	1.17

[1] Adapted from Table A6-5 Lambda Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-8. Ductility Factor Mu (μ) for All Model Building Types[1]

No. of Stories	*Mu Factor*
1	6.00
2	6.00
3	4.94
4	4.41
5	4.07
6	3.82
7	3.63
8	3.48
9	3.35
10	3.24
11	3.15
12	3.07
13	3.00
14	3.00
>=15	3.00

[1] Adapted from Table A6-6, Ductility Factor *Mu*, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-9. Elastic Damping (β_E) by Model Building Type[1]

Model Building Type	*Elastic Damping (% of Critical)*
S1, S2, S3, S4, and MH	5
CI, C2, PC1, and PC2	7
RM1 and RM2	7
C3 and S5	7
W1, W2, and URM	10

[1] Adapted from Table A6-7, Elastic Damping, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-10. Degradation Kappa Factors for Pre-Retrofit Condition[1] for Buildings Built After 1997[2]

Model Building Type	*UBC Zone 4 or IBC Seismic Design Category D*	*UBC Zone 3 or IBC Seismic Design Category C*	*UBC Zones 2 and 3 or IBC Seismic Design Categories A and B*
W1	0.8	0.5	0.4
W2	0.6	0.4	0.3
S1	0.6	0.4	0.3
S2	0.5	0.3	0.2
S3	0.5	0.6	0.5
S4	0.5	0.4	0.3
S5	—	—	—
C1	0.6	0.4	0.3
C2	0.6	0.4	0.3
C3	—	—	—
PC1	0.5	0.4	0.3
PC2	0.5	0.3	0.2
RM1	0.6	0.4	0.3
RM2	0.6	0.4	0.3
URM	—	—	—
MH	0.4	0.2	0.2

[1] For the Post-Retrofit Condition, assume that the Kappa levels for 1980-1997 are achieved through retrofit.

[2] Adapted from Table A6-8, Degradation Kappa Factors, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022). The Minimum Distance Site to Fault and Maximum Magnitude will not be known. Values were developed based on Table 5.18 in Chapter 5 of the HAZUS Earthquake Technical Manual (FEMA, 2020), with modifications for nonductile types (pre-1995 S1, pre-1978 C1 and C2, and pre-1980 PC1).

Table B-11. Degradation Kappa Factors for Pre-Retrofit Condition[1] for Buildings Built from Pre-Code to 1997[2]

Model Building Type	*1976-1994 UBC, Zone 4*	*1976-1994 UBC, Zone 3*	*1976-1994 UBC, Zones 2 or 1*	*1961-1973 UBC, Zone 3*	*1961-1973 UBC, Zone 2*	*1961-1973 UBC, Zone 1*	*Pre-1961 UBC, Zone 3*	*Pre-1961 UBC, Zones 2 or 1*	*Pre-Code*
W1	0.6	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2
W2	0.5	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.2
S1	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.2
S2	0.5	0.4	0.3	0.3	0.2	0.2	0.3	0.2	0.2
S3	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.2
S4	0.5	0.4	0.3	0.3	0.2	0.2	0.3	0.2	0.2
S5	—	—	—	—	—	—	0.2	0.2	0.1
C1	0.6	0.5	0.4	0.4	0.3	0.2	0.3	0.2	0.2
C2	0.5	0.3	0.3	0.4	0.3	0.2	0.3	0.2	0.2
C3	—	—	—	—	—	—	0.2	0.2	0.1
PC1	0.4	0.3	0.2	0.2	0.2	0.1	0.2	0.2	0.1
PC2	0.4	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.2
RM1	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.2	0.2
RM2	0.5	0.4	0.3	0.4	0.3	0.2	0.3	0.2	0.2
URM	—	—	—	—	—	—	0.2	0.2	0.2
MH	0.4	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1

[1] For the Post-Retrofit Condition, assume that the Kappa levels for 1980-1997 are achieved through retrofit.

[2] Adapted from Table A6-8, Degradation Kappa Factors, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022). Values were developed based on Table 5.18 in Chapter 5 of the HAZUS Earthquake Technical Manual (FEMA, 2020), with modifications for nonductile types (pre-1995 S1, pre-1978 C1 and C2, and pre-1980 PC1).

Table B-12. Interstory Drift Ratio – Median Complete Structural Damage (Δc) for Model Building Types[1]

Model Building Type	*Baseline, Post-Retrofit[2]*	*Baseline, Pre-Retrofit and Post-1961*	*Baseline, Pre-Retrofit and Pre-1961*	*Sub-Base, Post-Retrofit*	*Sub-Base, Pre-Retrofit and Post-1961*	*Sub-Base, Pre-Retrofit and Pre-1961*	*Ultra Sub-Base, Post-1961*	*Ultra Sub-Base, Pre-1961*
W1 and W2 (MH)	0.075	0.075	0.075	0.06	0.06	0.06	0.038	0.038
S1, C1, S2, and C2	0.06	0.06	0.05	0.05	0.05	0.04	0.03	0.025
S3, S4, PC1, PC2, RM1, and RM2	0.053	0.053	0.044	0.044	0.044	0.035	0.027	0.022
S5, C3, and URM	0.035	—	0.035	0.035	0.035	0.028	—	0.018

[1] Adapted from Table A6-9, Interstory Drift Ratio – Median Complete Structural Damage, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

[2] Assumes that retrofit addresses identified deficiencies and increases ductility to achieve Baseline performance.

Table B-13. Interstory Drift Ratio – Median Complete Structural Damage (Δc) for PC1 Model Building Type[1]

Model Building Type	*Baseline, Post-Retrofit*	*Baseline, Pre-Retrofit and Post-1975*	*Baseline, Pre-Retrofit and Pre-1975*	*Sub-Base, Post-Retrofit*	*Sub-Base, Pre-Retrofit and Post-1975*	*Sub-Base, Pre-Retrofit and Pre-1975*	*Ultra Sub-Base, Post-1975*	*Ultra Sub-Base, Pre-1975*
PC1	0.053	0.053	0.03	0.04	0.04	0.02	0.03	0.01

[1] Adapted from Table A6-9, Interstory Drift Ratio – Median Complete Structural Damage, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-14. Alpha 3 (α3) Modal Shape Factor[1]

No. of Stories	*Baseline Performance*	*Sub-Base Performance*	*Ultra Sub-Base Performance*
1	1.00	1.00	1.00
2	1.21	1.62	2.03
3	1.35	2.04	2.50
4	1.45	2.36	2.50
5	1.54	2.63	2.50
6	1.62	2.87	2.50
7	1.69	3.07	2.50
8	1.75	3.26	2.50
9	1.81	3.43	2.50
10	1.86	3.59	2.50
11	1.91	3.73	2.50
12	1.96	3.87	2.50
13	2.00	4.00	2.50
14	2.04	4.00	2.50
>= 15	2.08	4.00	2.50

[1] Adapted from Table A6-10, Alpha 3 Modal Shape Factor, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022). Combine with the Corresponding Median Interstory Drift Ratios for Complete Structural Damage.in Tables B-12 or B-13.

Table B-15. Lognormal Standard Deviation (Beta) Values – Complete Structural Damage (β_C)[1]

No. of Stories	*Baseline Performance, Post-1961*	*Baseline Performance, Pre-1961*	*Sub-Base Performance, Post-1961*	*Sub-Base Performance, Pre-1961*
1	0.85	0.90	0.95	1.00
2	0.85	0.90	0.95	1.00
3	0.85	0.90	0.95	1.00
4	0.84	0.89	0.94	0.99
5	0.83	0.88	0.93	0.98
6	0.82	0.87	0.92	0.97
7	0.81	0.86	0.91	0.96
8	0.80	0.85	0.90	0.95
9	0.79	0.84	0.89	0.94
10	0.78	0.83	0.88	0.93
11	0.77	0.82	0.87	0.92
12	0.76	0.81	0.86	0.91
13	0.75	0.80	0.85	0.90
14	0.75	0.80	0.85	0.90
> =15	0.75	0.80	0.85	0.90

[1] Adapted from Table A6-11, Lognormal Standard Deviation (Beta) Values – Complete Structural Damage, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-16. Modified Collapse Factor, Accounting for Nonstructural Deficiencies Affecting Life-Safety ("Good" Nonstructural[1])[2]

Model Building Type	*Baseline Performance*	*Sub-Base Performance*	*Ultra Sub-Base Performance*
W1, W2, and MH	0.05	0.1	0.2
S1, S2, S3, S4, and S5	0.08	0.15	0.3
C1, C2, and C3	0.13	0.25	0.5
RM1, RM2, and URM	0.13	0.25	0.5
PC1 and PC2	0.15	0.3	0.6

[1] For information about the "Good" rating, see Section 3.6.2 of this methodology report.

[2] Adapted from Table A6-12, Collapse Factor – Likelihood of Collapse Given Complete Structural Damage, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-17. Modified Collapse Factor, Accounting for Nonstructural Deficiencies Affecting Life-Safety ("Fair" Nonstructural[1])[2]

Model Building Type	*Baseline Performance*	*Sub-Base Performance*	*Ultra Sub-Base Performance*
W1, W2, and MH	0.1	0.15	0.25
S1, S2, S3, S4, and S5	0.13	0.2	0.35
C1, C2, and C3	0.18	0.3	0.55
RM1, RM2, and URM	0.18	0.3	0.55
PC1 and PC2	0.2	0.35	0.65

[1] For information about the "Fair" rating, see Section 3.6.2 of this methodology report. All values are increased by 0.05 from "Good" to give credit for retrofits of nonstructural items that present a life-safety hazard.

[2] Adapted from Table A6-12, Collapse Factor – Likelihood of Collapse Given Complete Structural Damage, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).

Table B-18. Modified Collapse Factor, Accounting for Nonstructural Deficiencies Affecting Life-Safety ("Poor" Nonstructural[1])[2]

Model Building Type	*Collapse Factor Baseline Performance*	*Collapse Factor Sub-Base Performance*	*Collapse Factor Ultra Sub-Base Performance*
W1, W2, and MH	0.15	0.2	0.3
S1, S2, S3, S4, and S5	0.18	0.25	0.4
C1, C2, and C3	0.23	0.35	0.6
RM1, RM2, and URM	0.23	0.35	0.6
PC1 and PC2	0.25	0.4	0.7

[1] For information about the "Poor" rating, see Section 3.6.2 of this methodology report. All values are increased by 0.10 from "Good" to give credit for retrofits of nonstructural items that present a life-safety hazard.

[2] Adapted from Table A6-12, Collapse Factor – Likelihood of Collapse Given Complete Structural Damage, Appendix H of Chapter 6, HAZUS AEBM Regulations (CAC, 2022).