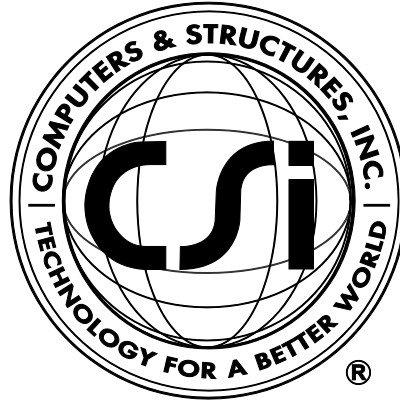# COMPUTERS & STRUCTURES, INC.

STRUCTURAL AND EARTHQUAKE ENGINEERING SOFTWARE

SAP 2000®

version 19

Integrated Solution for
Structural Analysis and Design

Automated Lateral Loads

Automated
Lateral Loads Manual

For SAP2000®

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Chapter 1
Introduction

SAP2000, ETABS, and CSiBridge are extremely powerful and productive structural analysis and design programs, partially due to the high level of intelligence embedded within the software. What this means is that many of the capabilities are highly automated, allowing the user to create and analyze the models in such a way that is both natural and efficient for a structural engineer. This manual seeks to explain the logic behind the automated lateral load generation so that users can gain greater insight into the behavior of the programs, and hence, greater confidence in their models and analyses.

1.1   About the Manual

The next chapter will show how seismic loads are generated for various codes, including a detailed discussion of the algorithms used. Chapter 3 does the same for automatic wind loads, again describing both the forms used and the accompanying algorithms.

It is strongly recommended that you read this manual and review any applicable "Watch & Learn" Series tutorials before attempting to use the automated features of the software. Additional information can be found in the on-line Help facility available from within the program's main menu.

Chapter 2
Automatic Seismic Loads

This chapter documents the automatic seismic lateral load patterns that can be generated. Automatic seismic loads can be generated in the global X or global Y directions for the following codes:

- 1994 UBC
- 1997 UBC
- 1997 UBC Isolated Building
- 1996 BOCA
- 1995 NBCC
- 2005 NBCC
- 2010 NBCC
- 2015 NBCC
- 2003 IBC / ASCE 7-02
- 2006 IBC / ASCE 7-05
- 2009 IBC / ASCE 7-05
- 2012 IBC/ ASCE 7-10
- 1997 NEHRP

- 2010 Chinese
- 2004 NZS 1170.5
- 2007 AS 1170.4
- 2004 Eurocode 8
- 2002 Indian IS:1893
- 2008 Italian NTC
- 2007 Turkish Seismic Code (TSC)
- 2009 Korean Building Code (KBC)
- 2009 Korean Building Code (KBC)
- 2011 Dominican Republic –R-001

2.1 Defining Automatic Seismic Load Patterns

The automatic seismic static load patterns are defined using the **Define** menu > **Load Patterns** command in SAP2000 and ETABS or the **Loads > Load Patterns > Load Patterns** command in CSiBridge. Those commands display the Define Load Patterns form. Use that form to specify a name for the load pattern, the type of load, a self-weight multiplier, and in some instances, specify that the load is an Auto Lateral Load Pattern.

When the load type is specified as Quake, the Auto Lateral Load drop-down list becomes active; use the list to choose any of the codes identified in the preceding section. Select *None* for the Auto Lateral Load to specify that the Quake load will *not* be an automatic lateral load.

If a code is selected in the Auto Lateral Load list when the **Add New Load Pattern** or **Modify Load Pattern** button is clicked, the load pattern is added to the model using default settings that are based on the selected code. To review or modify the parameters for an automatic lateral load, highlight the load in the Load list and click the **Modify Lateral Load Pattern** button.

In SAP2000 and CSiBridge, each automatic static lateral load must be in a separate load pattern. That is, two or more automatic static lateral loads cannot be specified in the same load pattern. However, additional user defined loads can be added to a load pattern that includes an automatic static lateral load.

In SAP2000 and CSiBridge, a separate automatic static load pattern must be defined for each direction, and, in the case of seismic loading, for each eccentricity that is to be considered. For example, to define automatic seismic lateral loads based on the 1997 UBC for X-direction load with no eccentricity, X-direction load with +5% eccentricity, and X-direction load with –5% eccentricity, three separate load patterns must be defined.

Note that the actual forces associated with an automatic static lateral load are not calculated until an analysis has been run. Thus, the resultant automatic lateral loads cannot be reviewed until after an analysis has been run.

2.2   Automatic Seismic Load Patterns

The forms defining the automatic seismic loads consist of various data sections, some of which are dependent upon the direction of the loading.

Some of the direction-dependent data is common to all of the codes. This includes the direction and eccentricity data and the story/elevation range data. These data are described in the subsections that follow because they are applicable to all codes. Other direction-dependent data, including building period information and other factors, and coefficients and the non-direction-dependent factors and coefficients are described separately for each code later in this chapter.

The weight of the structure used in the calculation of automatic seismic loads is based on the specified mass of the structure.

In ETABS, seismic load patterns may become multi-stepped. For example, a seismic load may be applied in multiple directions with and without eccentricities. These will be treated as a single load pattern and will be analyzed in a single load case, producing multiple output steps of response, one for each separate step of the load.

When a multi-stepped load pattern is applied in a load case, the following rules govern how it will be handled:

1. In a linear static load case, the load case will internally be run as a multi-linear static load case, producing multiple output steps.

2. In a nonlinear static load case, the load case will internally be run as a new type of staged-construction load case, where each stage starts from the beginning of the load case, producing results similar to the multi-linear static load case.

3. All other load cases (including staged-construction) are unchanged, and will treat the load pattern as single-stepped, using the first step of the multi-stepped load pattern.

4. For cases 1 and 2, if several multi-stepped load patterns are applied in a single load case, they superpose on a step-wise basis. For example, if load pattern A has 3 steps and load pattern B has 5 steps, the load case

will apply five independent load steps: A1+B1, A2+B2, A3+B3, B4, B5. If a non-stepped load pattern is applied, such as Dead, it is applied in every load step.

2.2.1 Types of Auto Seismic Loads

There are two types of auto seismic load patterns i.e. Seismic and Seismic (Drift) in ETABS. Seismic type pattern is used for strength design by including the load patterns in the default design combinations. The seismic type load pattern is documented in details in sections 2.3 to 2.21.

Seismic (Drift) patterns can be specified for modeling serviceability cases where upper limits on time period is waved. Generally, Seismic (Drift) case is applicable to 1997 UBC, 1997 UBC, 1996 BOCA, 1997 NEHRP, ASCE 7-02, ASCE 7-05 and ASCE 7/10 codes. These auto lateral load patterns do not enforce the upper limit on time period when time period is "Program Computed". For ASCE 7-10 code, in addition the minimum base shear limit as specified in ASCE 7-10 Eqn. 12.8-5 or Eqn. 12.8-6 is not enforced. The remaining implementation remains same as Seismic pattern documented in section 2.3 to 2.21.

2.2.2 Distribution of Automatic Seismic Loads at a Story Level

The method that the program uses to calculate the seismic base shear and the associated story lateral forces is documented separately for each code later in this chapter. After the program has calculated a force for each level based on the automatic seismic load pattern, that force is apportioned to each point at the level elevation in proportion to its mass.

2.2.3 Load Direction and Diaphragm Eccentricity

Use the direction and eccentricity data to choose the Global X or Global Y direction of the load and the eccentricity associated with the load pattern for all diaphragms.

To apply an eccentricity, specify a ratio eccentricity that is applicable to all diaphragms. The default ratio is 0.05. The eccentricity options have meaning

only if the model has diaphragms—the programs ignore eccentricities where diaphragms are not present.

Where diaphragms are present, the programs calculate a maximum width of the diaphragm perpendicular to the direction of the seismic loading. This width is calculated by finding the maximum and minimum X or Y coordinates (depending on direction of load considered) of the points that are part of the diaphragm constraint and determining the distance between these maximum and minimum values.

After the appropriate diaphragm width has been determined, a moment is applied that is equal to the specified ratio eccentricity times the maximum width of the diaphragm perpendicular to the direction of the seismic loading times the total lateral force applied to the diaphragm. This moment is applied about the diaphragm center of mass to account for the eccentricity.

When defining eccentricities, click the **Overwrite** button to overwrite the eccentricity for any diaphragm at any level. Thus, it is possible to have different eccentricity ratios at different levels. Note that when the eccentricities are overridden, an actual distance from the center of mass of the rigid diaphragm, not a ratio, must be input.

When the eccentricities have been overridden, the eccentric moment is calculated as the specified eccentricity distance times the total lateral force applied to the diaphragm. This moment is again applied about the diaphragm center of mass to account for the eccentricity.

2.2.4 Story/Elevation Range Data

In the Story/Elevation range data, specify a top story/maximum elevation and a bottom story/minimum elevation. This specifies the elevation range over which the automatic static lateral loads are calculated.

In most instances, the top elevation would be specified as the uppermost level in the structure, typically the roof in a building. However, in some cases, it may be advantageous to specify a lower elevation as the top level for automatic seismic loads. For example, if a penthouse is included in a building model, the automatic lateral load calculation likely should be based on the building roof level, not the penthouse roof level, as the top elevation, with

additional user-defined load added to the load pattern to account for the penthouse.

The bottom elevation typically would be the base level, but this may not always be the case. For example, if a building has several below-grade levels and it is assumed that the seismic loads are transferred to the ground at ground level, it would be necessary to specify the bottom elevation to be above the base level.

Note that no seismic loads are calculated for the bottom story/minimum elevation.

2.3   1994 UBC Seismic Loads

2.3.1 Options for 1994 UBC Building Period

Three options are provided for the building period used in calculating the 1994 UBC automatic seismic loads. They are:

Method A: Calculate the period based on the Method A period discussed in Section 1628.2.2 of the 1994 UBC. The period is calculated using 1994 UBC Equation 28-3. The value used for C_t is user input and h_n is determined by ETABS from the input story level heights.

$$T_A = C_t \left(h_n \right)^{3/4}$$
     1994 UBC Equation 28-3

Note that the item C_t is always input in English units as specified in the code. A typical range of values for C_t is 0.020 to 0.035. The height h_n is measured from the elevation of the (top of the) specified bottom story level to the (top of the) specified top story level.

Program Calculated: ETABS starts with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{ETABS}. ETABS also calculates a period based on the Method A period discussed in Section 1628.2.2 of the 1994 UBC. The period is calculated using 1994 UBC Equation 28-3. The value used for C_t is user input and h_n is determined by ETABS from the input story

level heights. Call this period T_A. The building period, T, that ETABS chooses depends on the seismic zone factor, Z.

If $Z \geq 0.35$ (Zone 4) then:

If $T_{\text{ETABS}} \leq 1.30T_A$, then $T = T_{\text{ETABS}}$.

If $T_{\text{ETABS}} > 1.30T_A$, then $T = T_A$.

If $Z < 0.35$ (Zone 1, 2 or 3) then:

If $T_{\text{ETABS}} \leq 1.40T_A$, then $T = T_{\text{ETABS}}$.

If $T_{\text{ETABS}} > 1.40T_A$, then $T = T_A$.

User Defined: In this case, the user inputs a building period. ETABS uses this period in the calculations. It does not compare it against the Method A period. It is assumed that the user has completed this comparison before specifying the period.

2.3.2 Other Input Factors and Coefficients

The R_w factor is direction dependent. It is specified in 1994 UBC Table 16-N. A typical range of values for R_w is 4 to 12.

The seismic zone factor, Z, can be input in accordance with the code, which restricts it to one of the following values: 0.075, 0.15, 0.2, 0.3, 0.4 as specified in 1994 UBC Table 16-I. Alternatively the Z factor can be user-defined, which allows any value to be input.

The site coefficient for soil characteristics, S, can be 1, 1.2, 1.5 or 2. These correspond to soil types S_1, S_2, S_3 and S_4 in Table 16-J of the 1994 UBC. No other values can be input.

The seismic importance factor, I can be input as any value. See 1994 UBC Table 16-K. A typical range of values for I is 1.00 to 1.25.

2.3.3 Algorithm for 1994 UBC Seismic Loads

The algorithm for determining 1994 UBC seismic loads is based on Chapter 16, Section 1628 of the 1994 UBC. ETABS calculates a period as described in a preceding section entitled "Options for 1994 UBC Building Period."

A numerical coefficient, *C*, is calculated using 1994 UBC Equation 28-2.

$$C = \frac{1.25S}{T^{2/3}}$$

1994 UBC Equation 28-2

where,

S = Site coefficient for soil characteristics.

T = Building period.

If the value of *C* exceeds 2.75, then *C* is set equal to 2.75 for use in Equation 28-3. If the value of C/R_w is less than 0.075, then it is set equal to 0.075 for use in Equation 28-3.

The base shear, *V*, is calculated from 1994 UBC Equation 28-1.

$$V = \frac{ZIC}{R_w} W$$

Eqn. 281994 UBC Equation 28-1

where,

Z = Seismic zone factor.

I = Importance factor.

C = Numerical coefficient calculated in Equation 28-2.

R_w = Numerical factor specified in UBC Table 16-N.

W = Weight of the building (based on specified mass).

Note that the weight, *W*, that ETABS uses in Equation 28-3 is derived from the building mass.

The total base shear, *V*, is broken into a concentrated force applied to the top of the building and forces applied at each story level in accordance with 1994 UBC Equation 28-6:

$$V = F_t + \sum_{story=1}^{n} F_{story} \qquad \text{1994 UBC Equation 28-6}$$

where,

V = Building base shear.

F_t = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the building, F_t, is calculated as shown in 1994 UBC Equation 28-7:

$$\begin{aligned} &\text{If } T \leq 0.7 \text{ sec, then } F_t = 0 \\ &\text{If } T > 0.7 \text{ sec, then } F_t = 0.07TV \leq 0.25V \end{aligned} \qquad \text{1994 UBC Equation 28-7}$$

where,

T = Building period.

V = Building base shear.

The remaining portion of the base shear, $(V - F_t)$, is distributed over the height of the building in accordance with 1994 UBC Equation 28-8:

$$F_{story} = \frac{(V - F_t)\, w_{story}\, h_{story}}{\sum_{story=1}^{n} w_{story}\, h_{story}} \qquad \text{1994 UBC Equation 28-8}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

F_t =   Concentrated force at the top of the building.

w_{story} =   Weight of story level (based on specified mass).

h_{story} =   Story height, distance from base of building to story level.

n =   Number of story levels in the building.

2.4   1997 UBC Seismic Loads

2.4.1 Options for 1997 UBC Building Period

Three options are provided for the building period used in calculating the 1997 UBC automatic seismic loads. They are as follows:

- **Method A:** Calculate the period based on the Method A period discussed in Section 1630.2.2 of the 1997 UBC. The period is calculated using 1997 UBC Eqn. 30-8. The value used for C_t is user input, and h_n is determined from the level heights.

$$T_A = C_t \left(h_n \right)^{3/4} \qquad \text{(1997 UBC Eqn. 30-8)}$$

Note that the item C_t is always input in English units as specified in the code. A typical range of values for C_t is 0.020 to 0.035. The height h_n is measured from the elevation of the specified bottom story/minimum elevation level to the (top of the) specified top story/maximum elevation level.

- **Program Calculated:** The program starts with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. The program also calculates a period based on the Method A period discussed in Section 1630.2.2 of the 1997 UBC. The period is calculated using 1997 UBC Eqn. 30-8. The value used for C_t is user input, and h_n is determined from the level heights. Call this period T_A. The building period, T, that the program chooses depends on the seismic zone factor, Z.

  - If $Z \geq 0.35$ (Zone 4) then:

- If $T_{mode} \leq 1.30 T_A$, then $T = T_{mode}$.

- If $T_{mode} > 1.30 T_A$, then $T = T_A$.

- If $Z < 0.35$ (Zone 1, 2 or 3) then:

  - If $T_{mode} \leq 1.40 T_A$, then $T = T_{mode}$.

  - If $T_{mode} > 1.40 T_A$, then $T = T_A$.

- **User Defined:** With this option, the user inputs a structure period, which the program uses in the calculations. The program does not compare the period to the Method A period. It is assumed that this comparison has been completed before the period is specified.

2.4.2 Other Input Factors and Coefficients

The overstrength factor, R, and the force factor, Ω, are direction dependent. Both are specified in 1997 UBC Table 16-N. A typical range of values for R is 2.8 to 8.5. A typical range of values for Ω is 2.2 to 2.8.

The seismic coefficients C_a and C_v can be determined in accordance with the code or they can be user-defined. If C_a and C_v are user-defined, specify values for them. A typical range of values for C_a is 0.06 to 0.40 and larger if the near source factor N_a exceeds 1.0. A typical range of values for C_v is 0.06 to 0.96 and larger if the near source factor N_v exceeds 1.0.

If C_a and C_v are determined in accordance with code, specify a soil profile type and a seismic zone factor. The programs then use these parameters to determine C_a from 1997 UBC Table 16-Q and C_v from 1997 UBC Table 16-R.

The soil profile type can be S_A, S_B, S_C, S_D or S_E. These correspond to soil types S_A, S_B, S_C, S_D and S_E in Table 16-J of the 1997 UBC. No other values can be input. Note that soil profile type S_F is not allowed for the automatic 1997 UBC seismic loads.

The seismic zone factor, Z, is restricted to one of the following values, as specified in 1997 UBC Table 16-I: 0.075, 0.15, 0.2, 0.3, or 0.4.

Note that in 1997 UBC Table 16-Q the C_a value for $Z = 0.4$ has an additional factor, N_a. Similarly, in 1997 UBC Table 16-R, the C_v value for $Z = 0.4$ has an additional factor, N_v. The values for the near source factors, N_a and N_v, can be determined in accordance with the code or they can be user-defined. If N_a and N_v are user-defined, specify values for them. If they are determined in accordance with code, specify a seismic source type and a distance to the closest known seismic source. On the basis of the input for seismic source type and distance to the source, the programs determine N_a from 1997 UBC Table 16-S and N_v from 1997 UBC Table 16-T. The programs use linear interpolation for specified distances between those included in 1997 UBC Tables 16-S and 16-T.

The seismic source type can be A, B, or C. These correspond to seismic source types A, B, and C in Table 16-U of the 1997 UBC. No other values can be input.

The distance to the closest known seismic source should be input in kilometers (km).

The seismic importance factor, I, can be input as any value. See 1997 UBC Table 16-K. Note that the value from Table 16-K to be input for automatic seismic loads is I, not I_p or I_w. A typical range of values for I is 1.00 to 1.25.

2.4.3 Algorithm for 1997 UBC Seismic Loads

The algorithm for determining 1997 UBC seismic loads is based on Chapter 16, Section 1630.2 of the 1997 UBC. A period is calculated as described in a preceding section entitled "Options for 1997 UBC Building Period."

Initially the total design base shear, V, is calculated using (1997 UBC Eqn. 30-4). This base shear value is then checked against the limits specified in (1997 UBC Eqns. 30-5, 30-6 and 30-7) and modified as necessary to obtain the final base shear.

$$V = \frac{C_v I}{RT} W \qquad \text{(1997 UBC Eqn. 30-4)}$$

where,

$C_v = $ 1997 UBC seismic coefficient, C_v.

I = Importance factor.

R = Overstrength factor specified in UBC Table 16-N.

T = Building period.

W = Weight of the building (based on specified mass).

The total design base shear, V, need not exceed that specified in (1997 UBC Eqn. 30-5). If the base shear calculated in accordance with (1997 UBC Eqn. 30-4) exceeds that calculated in accordance with (1997 UBC Eqn. 30-5), the base shear is set equal to that calculated in accordance with (1997 UBC Eqn. 30-5).

$$V = \frac{2.5 C_a I}{R} W \qquad \text{(1997 UBC Eqn. 30-5)}$$

where,

C_a = 1997 UBC seismic coefficient, C_a.

and all other terms are as described for (1997 UBC Eqn. 30-4).

The total design base shear, V, cannot be less than that specified in (1997 UBC Eqn. 30-6). If the base shear calculated in accordance with (1997 UBC Eqn. 30-6) exceeds that calculated in accordance with (1997 UBC Eqn. 30-4), the base shear is set equal to that calculated in accordance with (1997 UBC Eqn. 30-5).

$$V = 0.11 C_a I W \qquad \text{(1997 UBC Eqn. 30-6)}$$

where all terms are as described previously for (1997 UBC Eqns. 30-4 and 30-5).

Finally, if the building is in seismic Zone 4, the total design base shear, V, cannot be less than that specified in (1997 UBC Eqn. 30-7). If the building is in seismic Zone 4 and the base shear calculated in accordance with (1997 UBC Eqn. 30-7) exceeds that calculated in accordance with (1997 UBC Eqns. 30-5 and 30-6), the base shear is set equal to that calculated in accordance with (1997 UBC Eqn. 30-7).

$$V = \frac{0.8ZN_v I}{R} W \qquad \text{(1997 UBC Eqn. 30-7)}$$

where,

Z = Seismic zone factor (0.40).

N_v = Near source factor, N_v.

I = Importance factor.

R = Overstrength factor specified in UBC Table 16-N.

W = Weight of the building (based on specified mass).

Note that the programs check (1997 UBC Eqn. 30-7) only if the seismic co-efficients, C_a and C_v, are determined in accordance with the code and the seismic zone factor Z is specified as 0.40. If the C_a and C_v coefficients are user specified, (1997 UBC Eqn. 30-7) is never checked.

Note that the weight, W, that is used in (1997 UBC Eqns. 30-4 through 30-7) is derived from the building mass.

The total base shear, V, is broken into a concentrated force applied to the top elevation/story and forces applied at each level/story in accordance with (1997 UBC Eqn. 30-13):

$$V = F_t + \sum_{story=1}^{n} F_{story} \qquad \text{(1997 UBC Eqn. 30-13)}$$

where,

V = Building base shear.

F_t = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the building, F_t, is calculated as shown in (1997 UBC Eqn. 30-14):

If $T \leq 0.7$ sec, then $F_{\mathrm{t}} = 0$

If $T > 0.7$ sec, then $F_{\mathrm{t}} = 0.07TV \leq 0.25V$

(1997 UBC Eqn. 30-14)

where,

T = Building period.

V = Building base shear.

The remaining portion of the base shear, $(V - F_t)$, is distributed over the height of the structure in accordance with (1997 UBC Eqn 30-15):

$$F_{\mathrm{story}} = \frac{\left(V - F_t\right) w_{\mathrm{story}} \, h_{\mathrm{story}}}{\displaystyle\sum_{\mathrm{story}=1}^{\mathrm{n}} w_{\mathrm{story}} \, h_{\mathrm{story}}}$$

(1997 UBC Eqn. 30-15)

where,

F_{story} = Portion of base shear applied to a story level.

V = Base shear.

F_t = Concentrated force at the top of the structure.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

n = Number of story levels in the structure.

2.5   1997 UBC Isolated Building Seismic Loads

2.5.1 Other Input Factors and Coefficients

For 1997 UBC isolated building seismic loads, the bottom story or minimum elevation should be input as the story at the top of the isolators.

The overstrength factor, R_i, is direction dependent. It relates to the structure above the isolation interface. It is specified in 1997 UBC Table A-16-E,

which is in Appendix Chapter 16, Division IV. A typical range of values for R_i is 1.4 to 2.0.

The coefficient for damping, B_D, is direction dependent. It should be specified based on an assumed effective damping using 1997 UBC Table A-16-C, which is in Appendix Chapter 16, Division IV. A typical range of values for B_D is 0.8 to 2.0.

The maximum effective stiffness and minimum effective stiffness items refer to the maximum and minimum effective stiffness of the isolation system (not individual isolators) at the design displacement level (not the maximum displacement level). They correspond to the terms K_{Dmax} and K_{Dmin}, respectively, in Appendix Chapter 16, Division IV.

The seismic coefficient C_{vD} can be determined in accordance with the code or it can be user defined. If C_{vD} is user defined, simply specify a value for it. A typical range of values for C_{vD} is 0.06 to 0.96 and larger if the near source factor N_v exceeds 1.0.

If C_{vD} is determined in accordance with the code, specify a soil profile type and a seismic zone factor. On the basis of the input soil profile type and a seismic zone factor, the programs determine C_{vD} from 1997 UBC Table 16-R, which is in Chapter 16, not Appendix Chapter 16, Division IV.

Note that in 1997 UBC Table 16-R, the C_v value for $Z = 0.4$ has an additional factor, N_v. The value for this near source factor, N_v, can be determined in accordance with the code or it can be user defined. If N_v is user defined, simply specify a value for it. If it is determined in accordance with the code, specify a seismic source type and a distance to the closest known seismic source. On the basis of the input seismic source type and distance to the source, the programs determine N_v from 1997 UBC Table 16-T. The programs use linear interpolation for specified distances between those included in 1997 UBC Table 16-T.

2.5.2 Algorithm for 1997 UBC Isolated Building Seismic Loads

The algorithm for determining 1997 UBC seismic loads for isolated buildings is based on Appendix Chapter 16, Division IV, Sections 1658.3 and 1658.4 of the 1997 UBC.

The effective period at the design displacement, T_D, is determined from (1997 UBC Eqn. 58-2).

$$T_D = 2\pi \sqrt{\frac{W}{k_{D\min}\, g}}$$ (1997 UBC Eqn. 58-2)

where,

W =   Weight of the building (based on specified mass).

$k_{D\min}$ =   Minimum effective stiffness of the isolation system at the design displacement.

g =   Gravity constant, (e.g., 386.4 in/sec², 9.81 m/sec², etc.).

The design displacement at the center of rigidity of the isolation system, D_D, is determined from (1997 UBC Eqn. 58-1).

$$D_D = \frac{\left(\dfrac{g}{4\pi^2}\right) C_{vD} T_D}{B_D}$$ (1997 UBC Eqn. 58-1)

where,

g =   Gravity constant, (e.g., 386.4 in/sec², 9.81 m/sec², etc.).

C_{vD} =   Seismic coefficient, C_{vD}.

T_D =   Effective period at the design displacement.

B_D =   Coefficient for damping.

The base shear, V_s, is calculated from (1997 UBC Eqn. 58-8).

$$V_s = \frac{k_{D\max} D_D}{R_I}$$ (1997 UBC Eqn. 58-8)

Note that (1997 UBC Eqn. 58-8) gives a force level that is applicable for the structure above the isolation system. To use a force level that is applicable to the isolation system in accordance with (1997 UBC Eqn. 58-7), create a different load combination with a scale factor of R_I for the seismic load.

Also note that the limits on V_s specified in 1997 UBC section 1658.4.3 are not considered by the programs.

The total base shear, V_s, is distributed over the height of the structure in accordance with (1997 UBC Eqn. 58-9):

$$F_{\text{story}} = \frac{V_s \, w_{\text{story}} \, h_{\text{story}}}{\displaystyle\sum_{i=\text{story}}^{n} w_{\text{story}} \, h_{\text{story}}} \qquad\qquad \text{(1997 UBC Eqn. 58-9)}$$

where,

$F_{\text{story}} =$ Portion of base shear applied to a story level.

$V_s \quad =$ Base shear in accordance with (1997 UBC Eqn. 58-8).

$w_{\text{story}} =$ Weight of story level (based on specified mass).

$h_{\text{story}} =$ Story height, distance from base of structure to story level.

$n \quad =$ Number of story levels in the structure.

2.6   1996 BOCA Seismic Loads

2.6.1 Options for 1996 BOCA Building Period

Three options are provided for the building period used in calculating the 1996 BOCA automatic seismic loads. They are:

- **Approximate:** Calculate the approximate period, T_a, based on the approximate formula discussed in Section 1610.4.1.2.1 of the 1996 BOCA. The period is calculated using BOCA 1610.4.1.2.1. The value used for C_T is user input and h_n is determined from the input level heights.

$$T_a = C_T \left(h_n \right)^{3/4} \qquad\qquad \text{(BOCA 1610.4.1.2.1)}$$

Note that the item C_T is always input in English units as specified in the code. A typical range of values for C_T is 0.020 to 0.035. The height h_n is

measured from the elevation of the specified bottom story/minimum elevation level to the (top of the) specified top story/maximum elevation level.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. The programs also calculate a period based on the approximate formula discussed in Section 1610.4.1.2.1 of 1996 BOCA. The value used for C_T is user input and h_n is determined from the level heights. Call this period T_a.

  The programs determine a value for the coefficient for the upper limit on the calculated period, C_a, using Table 1610.4.1.2 in the 1996 BOCA. Note that the value used for C_a depends on the specified value for the effective peak velocity-related coefficient, A_v. C_a is determined using linear interpolation if the specified value of A_v is not in Table 1610.4.1.2. If A_v exceeds 0.40, C_a is taken as 1.2. If A_v is less than 0.05, C_a is taken as 1.7.

  The building period, T, that the programs choose is determined as follows:

  - If $T_{mode} > C_a T_a$, then $T = C_a T_a$.

  - If $T_{mode} \le C_a T_a$, then $T = T_{mode}$.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against the coefficient for the upper limit on the calculated period times the approximate period ($C_a T_a$). It is assumed that this comparison is performed before the period is specified.

2.6.2 Other Input Factors and Coefficients

The response modification factor, R, is direction dependent. It is specified in 1996 BOCA Table 1610.3.3. A typical range of values for R is 3 to 8.

Any value can be input for the effective peak acceleration coefficient, A_a. Refer to BOCA section 1610.1.3. A typical range of values for A_a is 0.05 to 0.40.

Any value can be input for the effective peak velocity-related coefficient, A_v. Refer to BOCA section 1610.1.3. A typical range of values for A_v is 0.05 to 0.40.

The soil profile type can be S_1, S_2, S_3 or S_4. These correspond to soil types S_1, S_2, S_3 and S_4 in Table 1610.3.1 of the 1996 BOCA. No other values can be input.

2.6.3 Algorithm for 1996 BOCA Seismic Loads

The algorithm for determining 1996 BOCA seismic loads is based on Section 1610.4.1 of 1996 BOCA. A period is calculated as described in the previous section entitled "Options for 1996 BOCA Building Period."

Initially the seismic coefficient, C_s, is calculated from section 1610.4.1.1. The value of this coefficient is then checked against the limit specified in (1996 BOCA Eqn. 1610.4.1.1) and modified as necessary to obtain the seismic coefficient.

$$C_s = \frac{1.2 A_v S}{R T^{2/3}}$$ (BOCA 1610.4.1.1(a))

where,

$A_v = $ The effective peak velocity-related coefficient.

$S\ = $ The site coefficient based on the input soil profile type.

$R\ = $ Response modification factor.

$T\ = $ Building period.

The seismic coefficient, C_s, need not exceed that specified in section 1610.4.1.1(b). If the seismic coefficient calculated in accordance with section 1610.4.1.1(a) exceeds that calculated in accordance with (BOCA Eqn. 1610.4.1.1(b)), the seismic coefficient is set equal to that calculated in accordance with (BOCA Eqn. 1610.4.1.1(b)).

$$C_s = \frac{2.5 A_a}{R}$$ (BOCA 1610.4.1.1(b))

where,

A_a = The effective peak acceleration coefficient.

R = Response modification factor.

The base shear is calculated using (BOCA 1610.4.1.1).

$$V = C_s W \qquad \text{(BOCA 1610.4.1.1)}$$

where,

C_s = Seismic coefficient calculated from (BOCA Eqn. 1610.4.1.1(a)) or (BOCA Eqn. 1610.4.1.1(b)) as appropriate.

W = Weight of the structure (based on specified mass).

The base shear, V, is distributed over the height of the structure in accordance with (BOCA Eqn. 1610.4.2):

$$F_{\text{story}} = \frac{V \, w_{\text{story}} \, h_{\text{story}}^k}{\displaystyle\sum_{i=\text{story}}^{n} w_{\text{story}} \, h_{\text{story}}^k} \qquad \text{(BOCA 1610.4.2)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to structure height. The value of k depends on the value of the period, T, used for determining the base shear. If $T \leq 0.5$ seconds, $k = 1$. If $T \geq 2.5$ seconds, $k = 2$. If 0.5 seconds $< T < 2.5$ seconds, k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.7   1995 NBCC Seismic Loads

2.7.1 Options for 1995 NBCC Building Period

Five options are provided for the building period used in calculating the 1995 NBCC automatic seismic loads. They are as follows:

- **Code - Moment Frame:** Calculate the period as $0.1N$, where N is the number of stories in the structure based on the specified top and bottom story levels.

- **Code - Other:** Calculate the period, T, using section 4.1.9.1(7b):

$$T = \frac{0.09h_n}{\sqrt{D_s}} \qquad \text{(1995 NBCC Section 4.1.9.19(7b))}$$

where,

h_n = Height of the structure measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level measured in meters.

D_s = Length of wall or braced frame, which constitutes the main lateral-force-resisting system measured in meters.

- **Program Calculated - Moment Frame:** The programs use the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). In addition, the programs run a parallel calculation using a period equal to $0.1N$, where N is the number of stories in the structure based on the specified top and bottom story levels.

The equivalent lateral force at the base of the structure, V_e, is calculated using both periods. Call these values $V_{e\text{-mode}}$ and $V_{e\text{-}0.1N}$. The value of V_e to use is determined as follows:

– If $V_{e\text{-mode}} \geq 0.8\, V_{e\text{-}0.1N}$, then $V_e = V_{e\text{-mode}}$.

– If $V_{e\text{-mode}} < 0.8\, V_{e\text{-}0.1N}$, then $V_e = 0.8\, V_{e\text{-}0.1N}$.

- **Program Calculated - Other:** The programs use the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). In addition, the programs run a parallel calculation using a period calculated using (1995 NBCC Section 4.1.9.19(7b)).

  The equivalent lateral force at the base of the structure, V_e, is calculated using both periods. Call these values $V_{e\text{-mode}}$ and $V_{e\text{-Eqn (7b)}}$. The value of V_e to use is determined as follows:

  - If $V_{e\text{-mode}} \geq 0.8\ V_{e\text{-Eqn. (7b)}}$, then $V_e = V_{e\text{-mode}}$.

  - If $V_{e\text{-mode}} < 0.8\ V_{e\text{-Eqn. (7b)}}$, then $V_e = 0.8\ V_{e\text{-Eqn. (7b)}}$.

- **User Defined:** In this case the user inputs a building period, which the programs use in the calculations. The programs do not calculate other values of V_e using this method for comparison against the V_e calculated using the user-specified period. It is assumed that this comparison is completed before the period is specified.

2.7.2 Other Input Factors and Coefficients

The force modification factor, R, is direction dependent. It is specified in 1995 NBCC Table 4.1.9.1.B. A typical range of values for R is 1.5 to 4.0.

The acceleration-related seismic zone, Z_a, can be input as 0, 1, 2, 3, 4, 5, or 6. No other input values are allowed.

The velocity-related seismic zone, Z_v, can be input as 0, 1, 2, 3, 4, 5, or 6. No other input values are allowed.

The zonal velocity ratio, v, can be based on Z_v, or a user-specified value can be input. If it is based on Z_v, v is assumed equal to 0.00, 0.05, 0.10, 0.15, 0.20, 0.30, or 0.40 for Z_v equal to 0, 1, 2, 3, 4, 5, or 6, respectively.

The importance factor, I, can be input as any value. It is specified in 1995 NBCC Sentence 4.1.9.1(10). A typical range of values for I is 1.0 to 1.5.

The foundation factor, F, can be input as any value. It is specified in 1995 NBCC Table 4.1.9.1.C. A typical range of values for F is 1.0 to 2.0.

2.7.3 Algorithm for 1995 NBCC Seismic Loads

The algorithm for determining 1995 NBCC seismic loads is based on Subsection 4.1.9 of the 1995 NBCC. The period is calculated as described in a preceding section entitled "Options for 1995 NBCC Building Period."

First the programs check if $Z_v = 0$ and $Z_a > 0$. If so, then $Z_v = 1$ and $v = 0.05$ is set for the calculation of the base shear.

The seismic response factor, S, is calculated based on 1995 NBCC Table 4.1.9.1.A.

The programs determine the product of the foundation factor, F, and the seismic response factor, S. Call this product FS. If necessary, this product is modified as follows:

- If $FS > 3$ and $Z_a \leq Z_v$, then $FS = 3$.

- If $FS > 4.2$ and $Z_a > Z_v$, then $FS = 4.2$.

The equivalent lateral force representing elastic response is determined in accordance with section 4.1.9.1(5):

$$V_e = v\,FS\,I \qquad\qquad \text{(1995 NBCC Section 4.1.9.1 (5))}$$

Note that in cases where the structure period is program calculated, the value of V_e is calculated twice and then one of the calculated values is chosen. See the preceding section entitled "Options for 1995 NBCC Building Period" for more information.

The minimum lateral seismic force, V, is calculated using section 4.1.9.1(4).

$$V = \frac{0.6V_e}{R} \qquad\qquad \text{(1995 NBCC Section 4.1.9.1(4))}$$

The total base shear, V, is broken into a concentrated force applied to the top of the structure and forces applied at each story level in accordance with section 4.1.9.1(13):

$$V = F_t + \sum_{story\,=\,1}^{n} F_{story} \qquad\qquad \text{(1995 NBCC Section 4.1.9.1(13))}$$

where,

V = Building base shear.

F_t = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the structure, F_t, is calculated as shown in section 4.1.9.1(13):

- If $T \leq 0.7$ sec, then $F_t = 0$
- If $T > 0.7$ sec, then $F_t = 0.07TV \leq 0.25V$

(1995 NBCC Section 4.1.9.1(13))

where,

T = Building period.

V = Building base shear.

The remaining portion of the base shear, $(V - F_t)$, is distributed over the height of the structure in accordance with (1995 NBCC Section 4.1.9.1(13)):

$$F_{story} = \frac{(V - F_t)\, w_{story}\, h_{story}}{\sum_{story\,=\,1}^{n} w_{story}\, h_{story}}$$

(1995 NBCC Section 4.1.9.1(13))

where,

F_{story} = Portion of base shear applied to a story level.

V = Base shear.

F_t = Concentrated force at the top of the structure.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

n = Number of story levels in the structure.

Note that the torsional moments discussed in 1995 NBCC Section 4.1.9.1(28) are included automatically when a diaphragm is present and eccentricity is specified in an auto lateral load pattern. Options are available to overwrite the eccentricities at each diaphragm to specify these torsional moments.

2.8 2005 NBCC Seismic Loads

2.8.1 Options for 2005 NBCC Building Period

Four options are provided for the building period used in calculating the 2005 NBCC automatic seismic loads. They are as follows:

- **Code – Steel & Concrete Moment Frames, Shear Wall & Other Structures:** Calculate the approximate period based on section 4.1.8.11(3). The values used for C_T and x are user input and h_n is determined by the programs from the input story level heights.

$$T_A = C_T \left(h_n \right)^{\frac{3}{4}} \qquad \text{(2005 NBCC Section 4.1.8.11(3))}$$

A typical range of values for C_T is 0.025 to 0.085. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level measured in meters.

- **Code – Moment Frames other than Steel & Concrete:** Calculate the approximate period, T_A, using section 4.1.8.11(3):

$$T_A = 0.1N \qquad \text{(2005 NBCC Section 4.1.8.11(3))}$$

where,

   N = The number of stories in the structure based on the specified top and bottom story levels.

- **Code – Braced Frame:** Calculate the approximate period, T_A, using section 4.1.8.11(3):

$$T_A = 0.025 \left(h_n \right) \qquad \text{(2005 NBCC Section 4.1.8.11(3))}$$

- ▪ **Program Calculated:** The programs use the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (*X* or *Y*). Call this period T_{mode}. A period is also calculated based on (NBCC Eqn. 4.1.8.11(3)), as appropriate. Call this period T_A.

  The building period, T, that the programs choose is determined from section 4.1.8.11(d). The values used for C_u are user input, and typically vary from 1.5 to 2.0 as specified in NBCC 2005 clause 4.1.8.11(3).

  - – If $T_{\mathrm{mode}} \leq C_u T_A$, then $T = T_{\mathrm{mode}}$. (NBCC 2005 Section 4.1.8.11(d))

  - – If $T_{\mathrm{mode}} > C_u T_A$, then $T = C_u T_A$. (NBCC 2005 Section 4.1.8.11(d))

- ▪ **User Defined:** In this case the user inputs a building period, which the programs use in the calculations. They do not compare it against $C_u T_A$. It is assumed that this comparison has been performed before the period is specified.

2.8.2 Other Input Factors and Coefficients

The ductility-related force modification factor, R_d, is direction dependent. It is specified in 2005 NBCC Table 4.1.8.9. A typical range of values for R_d is 1.5 to 5.0.

The overstrength-related force modification factor, R_o, is direction dependent. It is specified in 2005 NBCC Table 4.1.8.9. A typical range of values for R_o is 1.3 to 1.7.

The 5% damped spectral response acceleration, $S_a(T)$, shall be input for periods *T* of 0.2 s, 0.5 s, 1.0 s, and 2.0 s as described in subsection 4.1.8.4 of the 2005 NBCC. The input in the programs is in *g*.

The higher mode factor, M_v, is direction dependent. It is specified in 2005 NBCC Table 4.1.8.11. A typical range of values for M_v is 1 to 2.5.

The site coefficients can be input in accordance with the code or they can be user defined. If the site coefficients are in accordance with code, specify a site class. If site coefficients are user defined, specify F_a and F_v.

The site class can be A, B, C, D, or E. Note that site class F is not allowed for automatic 2005 NBCC lateral seismic loads. See 2005 NBCC Table 4.1.8.4.A for site class definitions.

F_a is the acceleration-based site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and $S_a(0.2)$ based on 2005 NBCC Table 4.1.8.4.B. If site coefficients are user defined, the value for F_a is input directly by the user. A typical range of values for F_a is 0.7 to 2.1.

F_v is the velocity-based site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and $S_a(1.0)$ based on 2005 NBCC Table 4.1.8.4.C. If site coefficients are user defined, the value for F_v is input directly by the user. A typical range of values for F_v is 0.5 to 2.1.

The importance factor, I_E, can be input as any value. It is specified in 2005 NBCC Sentence 4.1.8.5. A typical range of values for I_E is 0.8 to 1.5.

2.8.3 Algorithm for 2005 NBCC Seismic Loads

The algorithm for determining 2005 NBCC seismic loads is based on Subsection 4.1.8.11 of the 2005 NBCC. The period T is calculated as described in a preceding section entitled "Options for 2005 NBCC Building Period."

The programs begin by calculating the design spectral acceleration $S(T)$ using (2005 NBCC Eqns. 4.1.8.4(6)-1 to 4.1.8.4(6)-5). Linear interpolation is used for intermediate values of T. Eqns. 4.1.8.4(6)-1 to 4.1.8.4(6)-5 are described in Section 4.1.8.4 of 2005 NBCC.

$$S(T) = F_a S_a(0.2) \text{ for } T \le 0.2\,\text{s} \qquad \text{(2005 NBCC Eqn. 4.1.8.4(6)-1)}$$

$$S(T) = F_v S_a(0.5) \text{ or } F_a S_a(0.2),$$
$$\text{whichever is smaller for } T = 0.5\,\text{s} \qquad \text{(2005 NBCC Eqn. 4.1.8.4(6)-2)}$$

$$S(T) = F_v S_a(1.0) \text{ for } T = 1.0\,\text{s} \qquad \text{(2005 NBCC Eqn. 4.1.8.4(6)-3)}$$

$$S(T) = F_v S_a(2.0) \text{ for } T = 2.0\,\text{s} \qquad \text{(2005 NBCC Eqn. 4.1.8.4(6)-4)}$$

$$S(T) = F_v S_a(2.0)/2 \text{ for } T \geq 4.0\,\text{s} \qquad \text{(2005 NBCC Eqn. 4.1.8.4(6)-5)}$$

The minimum lateral earthquake force, V, is determined in accordance with (2005 NBCC Eqn. 4.1.8.11(2)-2):

$$V = S(T)M_v I_E W / (R_d R_o) \qquad \text{(2005 NBCC Eqn. 4.1.8.11(2)-1)}$$

where,

W = Weight of the building (based on specified mass).

The total design base shear, V, shall not be less than that specified in (2005 NBCC Eqn. 4.1.8.11(2)-2). If the base shear calculated in accordance with (2005 NBCC Eqn. 4.1.8.11(2)-1) is less than that calculated in accordance with (2005 NBCC Eqn. 4.1.8.11(2)-2), the base shear is set equal to that calculated in accordance with (2005 NBCC Eqn. 4.1.8.11(2)-2).

$$V = S(2.0)M_v I_E W / (R_d R_o) \qquad \text{(2005 NBCC Eqn. 4.1.8.11(2)-2)}$$

where,

$S(2.0)$ = Design spectral acceleration for a period of $2\,s$.

The total design base shear, V, for a structure with an $R_d \geq 1.5$ need not exceed that specified in (2005 NBCC Eqn. 4.1.8.11(2)-3). If the base shear calculated in accordance with (2005 NBCC Eqn. 4.1.8.11(2)-1) exceeds that calculated in accordance with (2005 NBCC Eqn. 24.1.8.11(2)-3), the base shear is set equal to that calculated in accordance with (2005 NBCC Eqn. 4.1.8.11(2)-3).

$$V = \frac{2}{3} S(0.2) I_E W / (R_d R_o) \qquad \text{(2005 NBCC Eqn. 4.1.8.11(2)-3)}$$

where,

$S(0.2)$ = Design spectral acceleration for $0.2\,s$.

The total base shear, V, is broken into a concentrated force applied to the top of the structure and forces applied at each story level in accordance with (2005 NBCC Eqn. 4.1.8.11(6)-1).

$$V = F_t + \sum_{story=1}^{n} F_{story} \qquad \text{(2005 NBCC Eqn. 4.1.8.11(6)-1)}$$

where,

V = Building base shear.

F_t = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the structure, F_t, is calculated as shown in (2005 NBCC Eqn. 4.1.8.11(6)-2):

- If $T \le 0.7 \text{ sec}$, then $F_t = 0$
- If $T > 0.7 \text{ sec}$, then $F_t = 0.07TV \le 0.25V$ (2005 NBCC Eqn. 4.1.8.11(6)-2)

where,

T = Building period.

V = Building base shear.

The remaining portion of the base shear, $(V - F_t)$, is distributed over the height of the structure in accordance with (2005 NBCC Eqn. 4.1.8.11(6)-3):

$$F_{story} = \frac{(V - F_t)\, w_{story}\, h_{story}}{\displaystyle\sum_{story=1}^{n} w_{story}\, h_{story}} \qquad \text{(2005 NBCC Eqn. 4.1.8.11(6)-3)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Base shear.

F_t = Concentrated force at the top of the structure.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

n = Number of story levels in the structure.

2.9   2010 NBCC Seismic Loads

2.9.1 Options for 2010 NBCC Building Period

Four options are provided for the building period used in calculating the 2010 NBCC automatic seismic loads. They are as follows:

- **Code – Steel & Concrete Moment Frames, Braced Frames, Shear Wall & Other Structures:** Calculate the approximate period based on section 4.1.8.11(3). The values used for C_T and x are user input, and h_n is determined by the programs from the input story level heights.

$$T_A = C_T \left(h_n \right)^{\frac{3}{4}} \qquad \text{(2010 NBCC Section 4.1.8.11(3))}$$

A typical range of values for C_T is 0.025 to 0.085. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level measured in meters.

- **Code – Moment Frames other than Steel & Concrete:** Calculate the approximate period, T_A, using section 4.1.8.11(3):

$$T_A = 0.1N \qquad \text{(2010 NBCC Section 4.1.8.11(3))}$$

where,

N = The number of stories in the structure based on the specified top and bottom story levels.

- **Code – Braced Frame:** Calculate the approximate period, T_A, using section 4.1.8.11(3):

$$T_A = 0.025 \left(h_n \right) \qquad \text{(2005 NBCC Section 4.1.8.11(3))}$$

- **Program Calculated:** The programs use the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period is also calculated based on (NBCC Eqn. 4.1.8.11(3)), as appropriate. Call this period T_A.

  The building period, T, that the programs choose is determined from section 4.1.8.11(d). The values used for C_u are user input, and typically vary from 1.5 to 2.0 as specified in NBCC 2010 clause 4.1.8.11(3).

    - If $T_{\text{mode}} \leq C_u T_A$, then $T = T_{\text{mode}}$. (NBCC 2010 Section 4.1.8.11(d))

    - If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$. (NBCC 2010 Section 4.1.8.11(d))

- **User Defined:** In this case the user can input a building period, which the programs use in the calculations. The programs do not compare it against $C_u T_A$. It is assumed that this comparison has been performed before specifying the period.

2.9.2 Other Input Factors and Coefficients

The ductility-related force modification factor, R_d, is direction dependent. It is specified in 2010 NBCC Table 4.1.8.9. A typical range of values for R_d is 1.5 to 5.0.

The overstrength-related force modification factor, R_o, is direction dependent. It is specified in 2010 NBCC Table 4.1.8.9. A typical range of values for R_o is 1.3 to 1.7.

The 5% damped spectral response acceleration, $S_a(T)$, shall be input for periods T of 0.2 s, 0.5 s, 1.0 s, and 2.0 s as described in subsection 4.1.8.4 of the 2010 NBCC. The input in the programs is in g.

The higher mode factor, M_v, is direction dependent. It is specified in 2010 NBCC Table 4.1.8.11. A typical range of values for M_v is 1 to 2.5.

The site coefficients can be input in accordance with the code or they can be user defined. If the site coefficients are in accordance with code, specify a site class. If site coefficients are user defined, specify F_a and F_v.

The site class can be A, B, C, D, or E. Note that site class F requires site specific evaluation for automatic 2010 NBCC lateral seismic loads. See 2010 NBCC Table 4.1.8.4.A for site class definitions.

F_a is the acceleration-based site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and $S_a(0.2)$ based on 2010 NBCC Table 4.1.8.4.B. If site coefficients are user defined, the value for F_a is input directly by the user. A typical range of values for F_a is 0.7 to 2.1.

F_v is the velocity-based site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and $S_a(1.0)$ based on 2010 NBCC Table 4.1.8.4.C. If site coefficients are user defined, the value for F_v is input directly by the user. A typical range of values for F_v is 0.5 to 2.1.

The importance factor, I_E, can be input as any value. It is specified in 2010 NBCC Sentence 4.1.8.5. A typical range of values for I_E is 0.8 to 1.5.

2.9.3 Algorithm for 2010 NBCC Seismic Loads

The algorithm for determining 2010 NBCC seismic loads is based on Subsection 4.1.8.11 of the 2010 NBCC. The period T is calculated as described in a preceding section entitled "Options for 2010 NBCC Building Period."

The programs begin by calculating the design spectral acceleration $S(T)$ using (2010 NBCC Eqns. 4.1.8.4(6)-1 to 4.1.8.4(6)-5). Linear interpolation is used for intermediate values of T. Eqns. 4.1.8.4(6)-1 to 4.1.8.4(6)-5 are described in Section 4.1.8.4 of the 2010 NBCC.

$$S(T) = F_a S_a(0.2) \text{ for } T \le 0.2 \text{ s} \qquad \text{(2010 NBCC Eqn. 4.1.8.4(6)-1)}$$

$$S(T) = F_v S_a(0.5) \text{ or } F_a S_a(0.2),$$
$$\text{whichever is smaller for } T = 0.5 \text{ s} \qquad \text{(2010 NBCC Eqn. 4.1.8.4(6)-2)}$$

$$S(T) = F_v S_a(1.0) \text{ for } T = 1.0 \text{ s} \qquad \text{(2010 NBCC Eqn. 4.1.8.4(6)-3)}$$

$$S(T) = F_v S_a(2.0) \text{ for } T = 2.0 \text{ s} \qquad \text{(2010 NBCC Eqn. 4.1.8.4(6)-4)}$$

$$S(T) = F_v S_a(2.0) / 2 \text{ for } T \ge 4.0 \text{ s} \qquad \text{(2010 NBCC Eqn. 4.1.8.4(6)-5)}$$

The minimum lateral earthquake force, V, is determined in accordance with (2010 NBCC Eqn. 4.1.8.11(2)-2):

$$V = S(T)M_v I_E W / (R_d R_o) \qquad \text{(2010 NBCC Eqn. 4.1.8.11(2)-1)}$$

where,

W = Weight of the building (based on specified mass).

The total design base shear, V, shall not be less than that specified in (2010 NBCC Eqn. 4.1.8.11(2)-2). If the base shear calculated in accordance with (2010 NBCC Eqn. 4.1.8.11(2)-1) is less than that calculated in accordance with (2010 NBCC Eqn. 4.1.8.11(2)-2), the base shear is set equal to that calculated in accordance with (2010 NBCC Eqn. 4.1.8.11(2)-2).

For walls, coupled walls and wall-frame system:

$$V = S(4.0)M_v I_E W / (R_d R_o) \qquad \text{(2010 NBCC Eqn. 4.1.8.11(2)-a)}$$

For moment resisting frame, braced frame and other systems:

$$V = S(2.0)M_v I_E W / (R_d R_o) \qquad \text{(2010 NBCC Eqn. 4.1.8.11(2)-b)}$$

where,

$S(2.0)$ = Design spectral acceleration for a period of 2 s.

$S(4.0)$ = Design spectral acceleration for a period of 4 s.

The total design base shear, V, for a structure Other than Site Class F and $R_d \geq 1.5$ need not exceed that specified in (2010 NBCC Eqn. 4.1.8.11(2)-3). If the base shear calculated in accordance with (2010 NBCC Eqn. 4.1.8.11(2)-1) exceeds that calculated in accordance with (2010 NBCC Eqn. 24.1.8.11(2)-3), the base shear is set equal to that calculated in accordance with (2010 NBCC Eqn. 4.1.8.11(2)-3).

$$V = \frac{2}{3}S(0.2)I_E W / (R_d R_o) \qquad \text{(2010 NBCC Eqn. 4.1.8.11(2)-3)}$$

where,

$S(0.2)$ = Design spectral acceleration for 0.2 s.

The total base shear, V, is broken into a concentrated force applied to the top of the structure and forces applied at each story level in accordance with (2010 NBCC Eqn. 4.1.8.11(6)-1).

$$V = F_t + \sum_{story=1}^{n} F_{story} \qquad \text{(2010 NBCC Eqn. 4.1.8.11(6)-1)}$$

where,

V = Building base shear.

F_t = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the structure, F_t, is calculated as shown in (2010 NBCC Eqn. 4.1.8.11(6)-2):

– If $T \leq 0.7$ sec, then $F_t = 0$

$\qquad\qquad\qquad\qquad\qquad\qquad$ (2010 NBCC Eqn. 4.1.8.11(6)-2)

– If $T > 0.7$ sec, then $F_t = 0.7TV \leq 0.25V$

where,

T = Building period.

V = Building base shear.

The remaining portion of the base shear, $(V - F_t)$, is distributed over the height of the structure in accordance with (2010 NBCC Eqn. 4.1.8.11(6)-3):

$$F_{story} = \frac{(V - F_t)\, w_{story}\, h_{story}}{\sum_{story=1}^{n} w_{story}\, h_{story}} \qquad \text{(2010 NBCC Eqn. 4.1.8.11(6)-3)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Base shear.

$$F_t \quad = \quad \text{Concentrated force at the top of the structure.}$$

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

n = Number of story levels in the structure.

2.10 2015 NBCC Seismic Loads

2.10.1 Options for 2015 NBCC Building Period

Four options are provided for the building period used in calculating the 2015 NBCC automatic seismic loads. They are as follows:

- **Code – Steel & Concrete Moment Frames, Braced Frames, Shear Wall & Other Structures:** Calculate the approximate period based on section 4.1.8.1(7). The values used for C_T and x are user input, and h_n is determined by the programs from the input story level heights.

$$T_A = C_T \left(h_n \right)^{\frac{3}{4}} \qquad \text{(2015 NBCC Section 4.1.8.11(3))}$$

A typical range of values for C_T is 0.025 to 0.085. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level measured in meters.

- **Code – Moment Frames other than Steel & Concrete:** Calculate the approximate period, T_A, using section 4.1.8.11(3):

$$T_A = 0.1N \qquad \text{(2015 NBCC Section 4.1.8.11(3))}$$

where,

N = The number of stories in the structure based on the specified top and bottom story levels.

- **Code – Braced Frame:** Calculate the approximate period, T_A, using section 4.1.8.11(3):

$$T_A = 0.025 \left(h_n \right) \qquad\qquad \text{(2005 NBCC Section 4.1.8.11(3))}$$

- **Program Calculated:** The programs use the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period is also calculated based on (NBCC Eqn. 4.1.8.11(3)), as appropriate. Call this period T_A.

  The building period, T, that the programs choose is determined from section 4.1.8.11(d). The values used for C_u are user input, and typically vary from 1.5 to 2.0 as specified in NBCC 2015 clause 4.1.8.11(3).

  - If $T_{\text{mode}} \le C_u T_A$, then $T = T_{\text{mode}}$. (NBCC 2015 Section 4.1.8.11.3(d))

  - If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$. (NBCC 2015 Section 4.1.8.11.3(d))

- **User Defined:** In this case the user can input a building period, which the programs use in the calculations. The programs do not compare it against $C_u T_A$. It is assumed that this comparison has been performed before specifying the period.

2.10.2   Other Input Factors and Coefficients

The ductility-related force modification factor, R_d, is direction dependent. It is specified in 2015 NBCC Table 4.1.8.9. A typical range of values for R_d is 1.5 to 5.0.

The overstrength-related force modification factor, R_o, is direction dependent. It is specified in 2015 NBCC Table 4.1.8.9. A typical range of values for R_o is 1.3 to 1.7.

The 5% damped spectral response acceleration, $S_a(T)$, shall be input for periods T of 0.2 s, 0.5 s, 1.0 s, 2.0 s, 5.0 s and 10.0 s as described in subsection 4.1.8.4 of the 2015 NBCC. The input in the programs is in g.

The higher mode factor, M_v, is direction dependent. It is specified in 2015 NBCC Table 4.1.8.11. A typical range of values for M_v is 1 to 4.65.

The site coefficients can be input in accordance with the code or they can be user defined. If the site coefficients are in accordance with code, specify a

site class. If site coefficients are user defined, specify F(0.2), F(0.5), F(1.0), F(2.0), F(5.0) and F(10.0).

The site class can be A, B, C, D, or E. Note that site class F requires site specific evaluation for automatic 2015 NBCC lateral seismic loads. See 2015 NBCC Table 4.1.8.4.A for site class definitions.

$F(0.2)$ is the acceleration-based site coefficient as described in 4.1.8.4(7). If the site coefficients are determined in accordance with code, the software automatically determines $F(0.2)$ from the site class and $S_a(0.2)$ based on 2015 NBCC Table 4.1.8.4.B. If site coefficients are user defined, the value for $F(0.2)$ is input directly by the user. A typical range of values for $F(0.2)$ is 0.69 to 1.64.

F(0.5) is the velocity-based site coefficient as described in 4.1.8.4(7). If the site coefficients are determined in accordance with code, the software automatically determines F(0.5) from the site class and $S_a(0.5)$ based on 2015 NBCC Table 4.1.8.4.C. If site coefficients are user defined, the value for F(0.5) is input directly by the user. A typical range of values for F(0.5) is 0.57 to 2.47.

F(1.0) is the velocity-based site coefficient as described in 4.1.8.4(7). If the site coefficients are determined in accordance with code, the software automatically determines F(1.0) from the site class and $S_a(1.0)$ based on 2015 NBCC Table 4.1.8.4.D. If site coefficients are user defined, the value for F(1.0) is input directly by the user. A typical range of values for F(1.0) is 0.57 to 2.81.

F(2.0) is the velocity-based site coefficient as described in 4.1.8.4(7). If the site coefficients are determined in accordance with code, the software automatically determines F(2.0) from the site class and $S_a(2.0)$ based on 2015 NBCC Table 4.1.8.4.E. If site coefficients are user defined, the value for F(2.0) is input directly by the user. A typical range of values for F(2.0) is 0.58 to 2.90.

F(5.0) is the velocity-based site coefficient as described in 4.1.8.4(7). If the site coefficients are determined in accordance with code, the software automatically determines F(5.0) from the site class and $S_a(5.0)$ based on 2015 NBCC Table 4.1.8.4.F. If site coefficients are user defined, the value for

F(5.0) is input directly by the user. A typical range of values for F(5.0) is 0.61 to 2.93.

F(10.0) is the velocity-based site coefficient as described in 4.1.8.4(7). If the site coefficients are determined in accordance with code, the software automatically determines F(10.0) from the site class and $S_a(10.0)$ based on 2015 NBCC Table 4.1.8.4.G. If site coefficients are user defined, the value for F(10.0) is input directly by the user. A typical range of values for F(10.0) is 0.67 to 2.52.

The importance factor, I_E, can be input as any value. It is specified in 2015 NBCC Sentence 4.1.8.5. A typical range of values for I_E is 0.8 to 1.5.

2.10.3 Algorithm for 2015 NBCC Seismic Loads

The algorithm for determining 2015 NBCC seismic loads is based on Subsection 4.1.8.11 of the 2015 NBCC. The period T is calculated as described in a preceding section entitled "Options for 2015 NBCC Building Period."

The programs begin by calculating the design spectral acceleration $S(T)$ using (2015 NBCC Eqns. 4.1.8.4(9)-1 to 4.1.8.4(9)-6). Linear interpolation is used for intermediate values of T. Eqns. 4.1.8.4(9)-1 to 4.1.8.4(9)-6 are described in Section 4.1.8.4 of the 2015 NBCC.

$$S(T) = F(0.2)S_a(0.2) \text{ or } F(0.5)S_a(0.5), \text{ whichever is larger for } T \le 0.2 \text{ s} \qquad \text{(2015 NBCC Eqn. 4.1.8.4(9)-1)}$$

$$S(T) = F(0.5)S_a(0.5) \text{ for } T = 0.5 \text{ s} \qquad \text{(2015 NBCC Eqn. 4.1.8.4(9)-2)}$$

$$S(T) = F(1.0)S_a(1.0) \text{ for } T = 1.0 \text{ s} \qquad \text{(2015 NBCC Eqn. 4.1.8.4(9)-3)}$$

$$S(T) = F(2.0)S_a(2.0) \text{ for } T = 2.0 \text{ s} \qquad \text{(2015 NBCC Eqn. 4.1.8.4(9)-4)}$$

$$S(T) = F(5.0)S_a(5.0) \text{ for } T = 5.0 \text{ s} \qquad \text{(2015 NBCC Eqn. 4.1.8.4(9)-5)}$$

$$S(T) = F(10.0)S_a(10.0) \text{ for } T = 10.0 \text{ s} \qquad \text{(2015 NBCC Eqn. 4.1.8.4(9)-6)}$$

The minimum lateral earthquake force, V, is determined in accordance with (2015 NBCC Eqn. 4.1.8.11(2)-2):

$$V = S(T)M_v I_E W / (R_d R_o) \qquad \text{(2015 NBCC Eqn. 4.1.8.11(2)-1)}$$

where,

W = Weight of the building (based on specified mass).

The total design base shear, V, shall not be less than that specified in (2015 NBCC Eqn. 4.1.8.11(2)-2). If the base shear calculated in accordance with (2015 NBCC Eqn. 4.1.8.11(2)-1) is less than that calculated in accordance with (2015 NBCC Eqn. 4.1.8.11(2)-2), the base shear is set equal to that calculated in accordance with (2015 NBCC Eqn. 4.1.8.11(2)-2).

For walls, coupled walls and wall-frame system:

$$V = S(4.0)M_v I_E W / (R_d R_o) \qquad \text{(2015 NBCC Eqn. 4.1.8.11(2)-a)}$$

For moment resisting frame, braced frame and other systems:

$$V = S(2.0)M_v I_E W / (R_d R_o) \qquad \text{(2015 NBCC Eqn. 4.1.8.11(2)-b)}$$

where,

$S(2.0)$ = Design spectral acceleration for a period of 2 s.

$S(4.0)$ = Design spectral acceleration for a period of 4 s.

The total design base shear, V, for a structure Other than Site Class F and $R_d \geq 1.5$ need not exceed that specified in (2015 NBCC Eqn. 4.1.8.11(2)-3). If the base shear calculated in accordance with (2015 NBCC Eqn. 4.1.8.11(2)-1) exceeds that calculated in accordance with (2015 NBCC Eqn. 24.1.8.11(2)-3), the base shear is set equal to that calculated in accordance with (2015 NBCC Eqn. 4.1.8.11(2)-3).

$$V = \text{larger of} \begin{cases} \dfrac{2}{3}S(0.2)I_E W / (R_d R_o) \\ S(0.5)I_E W / (R_d R_o) \end{cases} \qquad \text{(2015 NBCC Eqn. 4.1.8.11(2)-3)}$$

where,

$S(0.2)$ = Design spectral acceleration for 0.2 s.

$S(0.5)$ = Design spectral acceleration for 0.5 s.

The total base shear, V, is broken into a concentrated force applied to the top of the structure and forces applied at each story level in accordance with (2015 NBCC Eqn. 4.1.8.11(7)-1).

$$V = F_t + \sum_{story=1}^{n} F_{story} \qquad \text{(2015 NBCC Eqn. 4.1.8.11(7)-1)}$$

where,

V = Building base shear.

F_t = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the structure, F_t, is calculated as shown in (2015 NBCC Eqn. 4.1.8.11(7)-2):

– If $T \leq 0.7$ sec, then $F_t = 0$

– If $T > 0.7$ sec, then $F_t = 0.7TV \leq 0.25V$

(2015 NBCC Eqn. 4.1.8.11(7)-2)

where,

T = Building period.

V = Building base shear.

The remaining portion of the base shear, $(V - F_t)$, is distributed over the height of the structure in accordance with (2015 NBCC Eqn. 4.1.8.11(7)-3):

$$F_{story} = \frac{(V - F_t)\, w_{story}\, h_{story}}{\sum_{story=1}^{n} w_{story}\, h_{story}} \qquad \text{(2015 NBCC Eqn. 4.1.8.11(7)-3)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Base shear.

$$F_t \quad = \quad \text{Concentrated force at the top of the structure.}$$

$$w_{\text{story}} \quad = \quad \text{Weight of story level (based on specified mass).}$$

$$h_{\text{story}} \quad = \quad \text{Story height, distance from base of structure to story level.}$$

$$n \quad = \quad \text{Number of story levels in the structure.}$$

2.11   2003 IBC/ASCE 7-02 Seismic Loads

2.11.1   Options for 2003 IBC/ASCE 7-02 Building Period

Three options are provided for the building period used in calculating the 2003 IBC automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the period based on (ASCE 7-02, Eqn. 9.5.5.3.2-1). The value used for C_T is user input and h_n is determined by the programs from the input story level heights.

$$T_A = C_T \left(h_n \right)^x \qquad \text{(ASCE 7-02, Eqn. 9.5.5.3.2-1)}$$

Note that the item C_T is always input in English units as specified in the code. A typical range of values for C_T is 0.020 to 0.030. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level. x is determined using table 9.5.5.3.2 of ASCE 7-02.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period is also calculated based on (ASCE Eqn. 9.5.5.3.2-1). The value used for C_T is user input, and h_n is determined from the input story level heights. Call this period T_A.

The programs also calculate a coefficient for the upper limit on the calculated period, C_u. The building period, T, that the programs choose is determined as follows:

- If $T_{\text{mode}} \le C_u T_A$, then $T = T_{\text{mode}}$.

- If $T_{mode} > C_u T_A$, then $T = C_u T_A$.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against $C_u T_A$. It is assumed that this comparison is performed before the period is specified.

2.11.2   Other Input Factors and Coefficients

The response modification factor, R, and the system overstrength factor, Ω, are direction dependent. Both are specified in 2003 IBC Table 1617.6.2. A typical range of values for R is 2 to 8. A typical range of values for Ω is 2 to 3.

The seismic group can be input as I, II or III. No other values are allowed. See 2003 IBC Section 1616.2 for information about the seismic group. The programs determine the occupancy importance factor, I, from the input seismic group and 2003 IBC Table 1604.5.

The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, S_s and S_1. If seismic coefficients are user defined, specify S_s, S_1, F_a and F_v.

The site class can be A, B, C, D, or E. Note that site class F is not allowed for automatic 2003 IBC lateral seismic loads. See 2003 IBC Table 1615.1.1 for site class definitions.

S_s is the mapped spectral acceleration for short periods as determined in 2003 IBC Section 1615.1. A typical range of values for S_s is 0 to 3. Note that the seismic maps show S_s in % g with a typical range of 0% to 300%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 125%g, it should be input as 1.25g.

S_1 is the mapped spectral acceleration for a one second period as determined in 2003 IBC Section 1615.1. A typical range of values for S_1 is 0 to 2. Note that the seismic maps show S_1 in % g with a typical range of 0% to 200%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 125%g it should be input as 1.25g.

F_a is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and S_s based on 2003 IBC Table 1615.1.2(1). If site coefficients are user defined, F_a is input directly by the user. A typical range of values for F_a is 0.8 to 2.5.

F_v is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and S_1 based on 2003 IBC Table 1615.1.2(2). If site coefficients are user defined, F_v is input directly by the user. A typical range of values for F_v is 0.8 to 3.5.

2.11.3   Algorithm for 2003 IBC/ASCE 7-02 Seismic Loads

The algorithm for determining 2003 IBC seismic loads is based on 2003 IBC Section 1617.4. A period is calculated as described in a preceding section entitled "Options for 2003 IBC Building Period."

The programs begin by calculating the design spectral response acceleration at short periods, S_{DS}, using IBC Eqns. 16-38 and 16-40.

$$S_{DS} = \frac{2}{3} F_a S_s \qquad \text{(IBC Eqns. 16-38 and 16-40)}$$

Next, the design spectral response acceleration is calculated at a one second period, S_{D1}, using IBC Eqns. 16-39 and 16-41.

$$S_{D1} = \frac{2}{3} F_v S_1 \qquad \text{(IBC Eqns. 16-39 and 16-41)}$$

The programs determine a seismic design category (A, B, C, D, E, or F with A being the least severe and F being the most severe) based on 2003 IBC Section 1616.3. A seismic design category is determined based on S_{DS} using 2003 IBC Table 1616.3(1). A seismic design category also is determined based on S_{D1} using 2003 IBC Table 1616.3(2). The more severe of the two seismic categories is chosen as the seismic design category for the building.

Initially a seismic response coefficient, C_s, is calculated using (ASCE 7-02 Eqn. 9.5.5.2.1-1). This base shear value is then checked against the limits specified in (ASCE Eqns. 9.5.5.2.1-2, 9.5.5.2.1-3, and 9.5.5.2.1-4) and modified as necessary to obtain the final base shear.

$$C_s = \frac{S_{DS}}{\dfrac{R}{I}}$$
(ASCE 7-02 Eqn. 9.5.5.2.1-1)

where,

S_{DS} = The design spectral response acceleration at short periods.

R = Response modification factor specified in 2003 IBC Table 1617.6.2.

I = The occupancy importance factor determined in accordance with 2003 IBC Table 1604.5.

The seismic response coefficient, C_s, need not exceed that specified in (ASCE 7-02 Eqn. 9.5.5.2.1-2). If the seismic response coefficient calculated in accordance with (ASCE Eqn. 9.5.5.2.1.1-1) exceeds that calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-2), the programs set the seismic response coefficient, C_s, equal to that calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-2).

$$C_s = \frac{S_{D1}}{\left(\dfrac{R}{I}\right)T}$$
(ASCE 7-02 Eqn. 9.5.5.2.1-2)

where,

S_{D1} = the design spectral response acceleration at a one second period

T = the building period used for calculating the base shear

and all other terms are as described for (ASCE 7-02 Eqn. 9.5.5.2.1-1)

The seismic response coefficient, C_s, cannot be less than that specified in (ASCE 7-02 Eqn. 9.5.5.2.1-3). If the seismic response coefficient calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-3) exceeds that calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-1), the programs set the seismic response coefficient equal to that calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-3).

$$C_s = 0.044 \, S_{DS} \, I$$
(ASCE 7-02 Eqn. 9.5.5.2.1-3)

where all terms are as previously described for (ASCE 7-02 Eqn. 9.5.5.2.1-1)

Finally, if the building is in seismic design category E or F, the seismic response coefficient, C_s, shall not be less than that specified in (ASCE 7-02 Eqn. 9.5.5.2.1-4). If the building is in seismic design category E or F and the seismic response coefficient calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-4) exceeds that calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-1) and (ASCE Eqn. 7-02 9.5.5.2.1-3), the programs set the seismic response coefficient equal to that calculated in accordance with (ASCE 7-02 Eqn. 9.5.5.2.1-4).

$$C_s = \frac{0.5S_1}{\dfrac{R}{I}}$$ (ASCE 7-02 Eqn. 9.5.5.2.1-4)

where,

S_1 = the mapped spectral acceleration for a one second period

and all other terms are as previously described for (ASCE 7-02 Eqn. 9.5.5.2.1-1) .

The base shear, V, is calculated using (ASCE 7-02 Eqn. 9.5.5.2.-1)

$$V = C_s\, W$$ (ASCE 7-02 Eqn. 9.5.5.2.-1)

C_s = Seismic response coefficient as determined from one of (ASCE 7-02 Eqns. 9.5.5.2.1-1 through 9.5.5.2.1-4) as appropriate.

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (ASCE 7-02 Eqns. 9.5.5.4-1 and 9.5.5.4-2).

$$F_{story} = \frac{V\, w_{story}\, h_{story}^k}{\displaystyle\sum_{story=1}^{n} w_{story}\, h_{story}^k}$$ (Eqns. 9.5.5.4.-1 and 9.5.5.4-2)

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of k depends on the value of the building period, T, used for determining the base shear. If $T \leq 0.5$ seconds, then $k = 1$. If $T \geq 2.5$ seconds, then $k = 2$. If 0.5 seconds $< T < 2.5$ seconds, then k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.12   2006 IBC/ASCE 7-05 Seismic Loads

Section 1613 of the 2006 IBC states that earthquake loads shall be determined in accordance with ASCE Standard 7-05. For the sake of clarity, in the remainder of this section all references will be made only to the ASCE 7-05 document, with the understanding that this information is directly applicable to those using the 2006 IBC as well.

2.12.1   Options for 2006 IBC/ASCE 7-05 Building Period

Three options are provided for the building period used in calculating the 2006 IBC automatic seismic loads. They are as follows:

▪ **Approximate Period:** Calculate the period based on (ASCE 7-05 Eqn. 12.8-7) The values used for C_T and x are user input and h_n is determined by the programs from the input story level heights.

$$T_A = C_T \left(h_n \right)^x \qquad \text{(ASCE 7-05 Eqn. 12.8-7)}$$

Note that C_T is always input in English units, as specified in the code. A typical range of values for C_T is 0.016 to 0.03, while x varies from 0.75 to 0.9. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (*X* or *Y*). Call this period T_{mode}. A period is also calculated based on (ASCE 7-05 Eqn. 12.8-7). The values used for C_T and *x* are user input, and h_n is determined from the input story level heights. Call this period T_A.

  The programs also calculate a coefficient for the upper limit on the calculated period, C_u. The building period, *T*, that the programs choose is determined as follows:

  - If $T_{\text{mode}} \leq C_u T_A$, then $T = T_{\text{mode}}$.

  - If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against $C_u T_A$. It is assumed that this comparison is performed before the period is specified.

2.12.2 Other Input Factors and Coefficients

The response modification factor, *R*, and the system overstrength factor, Ω, are direction dependent. Both are specified in ASCE 7-05 Table 12.2-1. A typical range of values for *R* is 2 to 8. A typical range of values for Ω is 2 to 3.

The occupancy category can be input as I, II, III or IV. No other values are allowed. See ASCE 7-05 Section 11.5 for information about the occupancy category. The programs determine the occupancy importance factor, *I*, from the input occupancy category and ASCE 7-05 Table 11.5-1.

The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, S_s and S_1, as well as a long-period transition period, T_L. If seismic coefficients are user defined, specify S_s, S_1, T_L, F_a and F_v.

The site class can be A, B, C, D, or E. Note that site class F is not allowed for automatic ASCE 7-05 lateral seismic loads. See ASCE 7-05 Table 20.3-1 for site class definitions.

S_s is the mapped maximum considered earthquake (MCE) spectral acceleration for short periods as determined in ASCE 7-05 Section 11.4.1. A typical range of values for S_s is 0 to 3. Note that the seismic maps show S_s in % g with a typical range of 0% to 300%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 125%g it should be input as 1.25g.

S_1 is the mapped MCE spectral acceleration for a one second period as determined in ASCE 7-05 Section 11.4.1. A typical range of values for S_1 is 0 to 1. Note that the seismic maps show S_1 in %g with a typical range of 0% to 100%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 100%g it should be input as 1.0g.

F_a is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and S_s based on ASCE 7-05 Table 11.4-1. If site coefficients are user defined, the F_a is input directly by the user. A typical range of values for F_a is 0.8 to 2.5.

F_v is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and S_1 based on ASCE 7-05 Table 11.4-2. If site coefficients are user defined, F_v is input directly by the user. A typical range of values for F_v is 0.8 to 3.5.

T_L is the long-period transition period as determined in ASCE 7-05 Section 11.4.5.

2.12.3   Algorithm for ASCE 7-05 Seismic Loads

The algorithm for determining ASCE 7-05 seismic loads is based on ASCE 7-05 Section 12.8. A period is calculated as described in a preceding section entitled "Options for ASCE 7-05 Building Period."

The programs begin by calculating the design spectral response acceleration at short period, S_{DS}, using (ASCE 7-05 Eqs. 11.4-1 and 11.4-3).

$$S_{DS} = \frac{2}{3} F_a S_s \qquad \text{(ASCE 7-05 Eqns. 11.4-1 and 11.4-3)}$$

Next, the design spectral response acceleration is calculated at a one second period, S_{D1}, using (ASCE 7-05 Eqns. 11.4-2 and 11.4-3).

$$S_{D1} = \frac{2}{3} F_v S_1 \qquad \text{(ASCE 7-05 Eqns. 11.4-2 and 11.4-3)}$$

The programs determine a seismic design category (A, B, C, D, E, or F with A being the least severe and F being the most severe) based on ASCE 7-05 Section 11.6. A seismic design category is determined based on S_{DS} using ASCE 7-05 Table 11.6-1. A seismic design category also is determined based on S_{D1} using ASCE 7-05 Table 11.6-2. The more severe of the two seismic categories is chosen as the seismic design category for the building.

Initially a seismic response coefficient, C_s, is calculated using (ASCE 7-05 Eqn. 12.8-2). This base shear value is then checked against the limits specified in (ASCE 7-05 Eqns. 12.8-3, 12.8-4, 2.8-5, and 12.8-6) and modified as necessary to obtain the final base shear.

$$C_s = \frac{S_{DS}}{\dfrac{R}{I}} \qquad \text{(ASCE 7-05 Eqn. 12.8-2)}$$

where,

S_{DS} = The design spectral response acceleration at short periods.

R = Response modification factor specified in ASCE 7-05 Table 12.2-1.

I = The occupancy importance factor determined in accordance with ASCE 7-05 Table 11.5-1.

The seismic response coefficient, C_s, need not exceed that specified in (ASCE 7-05 Eqns. 12.8-3). If the seismic response coefficient calculated in accordance with (ASCE 7-05 Eqns. 12.8-2) exceeds that calculated in accordance with (ASCE 7-05 Eqns. 12.8-3 and 12.8-4), the programs set the seismic response coefficient, C_s, equal to that calculated in accordance with (ASCE 7-05 Eqns. 12.8-3 and 12.8-4), as appropriate.

$$C_s = \frac{S_{D1}}{\left(\frac{R}{I}\right)T} \quad \text{for } T \le T_L \qquad \text{(ASCE 7-05 Eqn. 12.8-3)}$$

$$C_s = \frac{S_{D1}T_L}{\left(\frac{R}{I}\right)T^2} \quad \text{for } T > T_L \qquad \text{(ASCE 7-05 Eqn. 12.8-4)}$$

where,

S_{D1} = the design spectral response acceleration at a one second period

T = the building period used for calculating the base shear

T_L = the long-period transition period

and all other terms are as described for (ASCE 7-05 Eqn. 12.8-2).

C_s shall not be less than that shown in (ASCE 7-05 Eqn. 12.8-5).

$$C_s = 0.044 S_{DS} I \ge 0.01 \qquad \text{(ASCE 7-05 Eqn. 12.8-5)}$$

Finally, for structures located where S_1 is equal to or greater than 0.6g, C_s shall not be less than that shown in (ASCE 7-05 Eqn. 12.8-6).

$$C_s = \frac{0.5 S_1}{\left(\frac{R}{I}\right)} \qquad \text{(ASCE 7-05 Eqn. 12.8-6)}$$

where,

S_1 = the mapped MCE spectral acceleration for a one second period

and all other terms are as described for (ASCE 7-05 Eqn. 12.8-2).

The base shear, V, is calculated using (ASCE 7-05 Eqn. 12.8-1):

V = $C_s W$ (ASCE 7-05 Eqn. 12.8-1)

C_s = Seismic response coefficient as determined from one of (ASCE 7-05 Eqns. 12.8-2 through 12.8-6) as appropriate.

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (ASCE 7-05 Eqns. 12.8-11 and 12.8-12)

$$F_{\text{story}} = \frac{V \ w_{\text{story}} \ h_{\text{story}}^{k}}{\displaystyle\sum_{\text{story}=1}^{n} w_{\text{story}} \ h_{\text{story}}^{k}} \qquad \text{(ASCE 7-05 Eqns. 12.8-11 and 12.8-12)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of k depends on the value of the building period, T, used to determine the base shear. If $T \leq 0.5$ second, $k = 1$. If $T \geq 2.5$ seconds, $k = 2$. If 0.5 second $< T < 2.5$ seconds, k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.13   2009 IBC/ASCE 7-05 Seismic Loads

Section 1613 of the 2009 IBC states that earthquake loads shall be determined in accordance with ASCE Standard 7-05. For the sake of clarity, in the remainder of this section all references will be made only to the ASCE 7- 05 document, with the understanding that this information is directly applicable to those using the 2009 IBC as well.

2.13.1   Options for 2009 IBC/ASCE 7-05 Building Period

Three options are provided for the building period used in calculating the 2009 IBC automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the period based on (ASCE 7-05 Eqn. 12.8-7). The values used for C_t and x are user input, and h_n is determined by the programs from the input story level heights.

$$T_A = C_t \left(h_n \right)^x \qquad \text{(ASCE 7-05 Eqn. 12.8-7)}$$

  Note that C_t is always input in English units, as specified in the code. A typical range of values for C_t is 0.016 to 0.03, while x varies from 0.75 to 0.9. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period is also calculated based on (ASCE 7-05 Eqn. 12.8-7). The values used for C_t and x are user input, and h_n is determined from the input story level heights. Call this period T_A.

  The programs also calculate a coefficient for the upper limit on the calculated period, C_u. The building period, T, that the programs choose is determined as follows:

  - If $T_{\text{mode}} \le C_u T_A$, then $T = T_{\text{mode}}$.

  - If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against $C_u T_A$. It is assumed that this comparison is performed before the period is specified.

2.13.2 Other Input Factors and Coefficients

The response modification factor, R, and the system overstrength factor, Ω_o, are direction dependent. Both are specified in ASCE 7-05 Table 12.2-1. A typical range of values for R is 2 to 8. A typical range of values for Ω_o is 2 to 3.

The occupancy category can be input as I, II, III or IV. No other values are allowed. See ASCE 7-05 Section 11.5 for information about the occupancy

category. The programs determine the occupancy importance factor, I, from the input occupancy category and ASCE 7-05 Table 11.5-1.

The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, S_s and S_1, as well as a long-period transition period, T_L. If seismic coefficients are user defined, specify S_s, S_1, T_L, F_a and F_v.

The site class can be A, B, C, D, or E. Note that site class F is not allowed for automatic ASCE 7-05 lateral seismic loads. See ASCE 7-05 Table 20.3-1 for site class definitions.

S_s is the mapped maximum considered earthquake (MCE) spectral acceleration for short periods as determined in ASCE 7-05 Section 11.4.1. A typical range of values for S_s is 0 to 3. Note that the seismic maps show S_s in % g with a typical range of 0% to 300%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 125%g it should be input as 1.25g.

S_1 is the mapped MCE spectral acceleration for a one second period as determined in ASCE 7-05 Section 11.4.1. A typical range of values for S_1 is 0 to 1. Note that the seismic maps show S_1 in %g with a typical range of 0% to 100%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 100%g, it should be input as 1.0g.

F_a is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and S_s based on ASCE 7-05 Table 11.4-1. If site coefficients are user defined, the F_a is input directly by the user. A typical range of values for F_a is 0.8 to 2.5.

F_v is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and S_1 based on ASCE 7-05 Table 11.4-2. If site coefficients are user defined, F_v is input directly by the user. A typical range of values for F_v is 0.8 to 3.5.

T_L is the long-period transition period as determined in ASCE 7-05 Section 11.4.5.

2.13.3   Algorithm for 2009 IBC/ASCE 7-05 Seismic Loads

The algorithm for determining ASCE 7-05 seismic loads is based on ASCE 7-05 Section 12.8. A period is calculated as described in a preceding section entitled "Options for ASCE 7-05 Building Period."

The programs begin by calculating the design spectral response acceleration at short period, S_{DS}, using (ASCE 7-05 Eqs. 11.4-1 and 11.4-3).

$$S_{DS} = \frac{2}{3} F_a S_s \qquad \text{(ASCE 7-05 Eqns. 11.4-1 and 11.4-3)}$$

Next, the design spectral response acceleration is calculated at a one second period, S_{D1}, using (ASCE 7-05 Eqns. 11.4-2 and 11.4-3).

$$S_{D1} = \frac{2}{3} F_v S_1 \qquad \text{(ASCE 7-05 Eqns. 11.4-2 and 11.4-3)}$$

The programs determine a seismic design category (A, B, C, D, E, or F with A being the least severe and F being the most severe) based on ASCE 7-05 Section 11.6. A seismic design category is determined based on S_{DS} using ASCE 7-05 Table 11.6-1. A seismic design category also is determined based on S_{D1} using ASCE 7-05 Table 11.6-2. The more severe of the two seismic categories is chosen as the seismic design category for the building.

Initially a seismic response coefficient, C_s, is calculated using (ASCE 7-05 Eqn. 12.8-2). This base shear value is then checked against the limits specified in (ASCE 7-05 Eqns. 12.8-3, 12.8-4, 2.8-5, and 12.8-6) and modified as necessary to obtain the final base shear.

$$C_s = \frac{S_{DS}}{\dfrac{R}{I_e}} \qquad \text{(ASCE 7-05 Eqn. 12.8-2)}$$

where,

   S_{DS} = The design spectral response acceleration at short periods.

   R = Response modification factor specified in ASCE 7-05 Table 12.2-1.

I_e = The occupancy importance factor determined in accordance with ASCE 7-05 Table 11.5-1.

The seismic response coefficient, C_s, need not exceed that specified in (ASCE 7-05 Eqns. 12.8-3 and 12.8-4). If the seismic response coefficient calculated in accordance with (ASCE 7-05 Eqns. 12.8-2) exceeds that calculated in accordance with (ASCE 7-05 Eqns. 12.8-3 and 12.8-4), the programs set the seismic response coefficient, C_s, equal to that calculated in accordance with (ASCE 7-05 Eqns. 12.8-3 and 12.8-4), as appropriate.

$$C_s = \frac{S_{D1}}{\left(\dfrac{R}{I_e}\right)T} \text{ for } T \leq T_L \qquad \text{(ASCE 7-05 Eqn. 12.8-3)}$$

$$C_s = \frac{S_{D1}\,T_L}{\left(\dfrac{R}{I_e}\right)T^2} \text{ for } T > T_L \qquad \text{(ASCE 7-05 Eqn. 12.8-4)}$$

where,

S_{D1} = the design spectral response acceleration at a one second period

T = the building period used for calculating the base shear

T_L = the long-period transition period

and all other terms are as described for (ASCE 7-05 Eqn. 12.8-2).

C_s shall not be less than that shown in (ASCE 7-05 Eqn. 12.8-5).

$$C_s = 0.044 S_{DS} I_e \geq 0.01 \qquad \text{(ASCE 7-05 Eqn. 12.8-5)}$$

Finally, for structures located where S_1 is equal to or greater than 0.6g, C_s shall not be less than that shown in (ASCE 7-05 Eqn. 12.8-6).

$$C_s = \frac{0.5 S_1}{\left(\dfrac{R}{I_e}\right)} \qquad \text{(ASCE 7-05 Eqn. 12.8-6)}$$

where,

S_1 = the mapped *MCE* spectral acceleration for a one second period

and all other terms are as described for (ASCE 7-05 Eqn. 12.8-2).

The base shear, *V*, is calculated using (ASCE 7-05 Eqn. 12.8-1):

$$V = C_s W \qquad \text{(ASCE 7-05 Eqn. 12.8-1)}$$

C_s = Seismic response coefficient as determined from one of (ASCE 7-05 Eqns. 12.8-2 through 12.8-6) as appropriate.

W = Weight of the building (based on specified mass).

The base shear, *V*, is distributed over the height of the building in accordance with (ASCE 7-05 Eqns. 12.8-11 and 12.8-12)

$$F_{\text{story}} = \frac{V \; w_{\text{story}} \; h_{\text{story}}^{k}}{\displaystyle\sum_{\text{story}=1}^{n} w_{\text{story}} \; h_{\text{story}}^{k}} \qquad \text{(ASCE 7-05 Eqns. 12.8-11 and 12.8-12)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of *k* depends on the value of the building period, *T*, used for determining the base shear. If $T \le 0.5$ seconds, $k = 1$. If $T \ge 2.5$ seconds, $k = 2$. If 0.5 seconds $< T < 2.5$ seconds, *k* is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.14   2012 IBC/ASCE 7-10 Seismic Loads

Section 1613 of the 2012 IBC states that earthquake loads shall be determined in accordance with ASCE Standard 7-10. For the sake of clarity, in the remainder of this section all references will be made only to the ASCE 7-10 document, with the understanding that this information is directly applicable to those using the 2012 IBC as well.

2.14.1   Options for 2012 IBC/ASCE 7-10 Building Period

Three options are provided for the building period used in calculating the ASCE 7-10 automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the period based on (ASCE 7-10 Eqn. 12.8-7). The values used for C_t and x are user input, and h_n is determined by the programs from the input story level heights.

$$T_A = C_t \left(h_n \right)^x \qquad \text{(ASCE 7-10 Eqn. 12.8-7)}$$

Note that C_t is always input in English units, as specified in the code. A typical range of values for C_t is 0.016 to 0.03, while x varies from 0.75 to 0.9. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period is also calculated based on (ASCE 7-10 Eqn. 12.8-7). The values used for C_t and x are user input, and h_n is determined from the input story level heights. Call this period T_A.

The programs also calculate a coefficient for the upper limit on the calculated period, C_u. The building period, T, that the programs choose is determined as follows:

  - If $T_{\text{mode}} \leq C_u T_A$, then $T = T_{\text{mode}}$.

  - If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$.

- ▪ **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against C_uT_A. It is assumed that this comparison is performed before the period is specified.

2.14.2   Other Input Factors and Coefficients

The response modification factor, R, and the system overstrength factor, Ω_o, are direction dependent. Both are specified in ASCE 7-10 Table 12.2-1. A typical range of values for R is 2 to 8. A typical range of values for Ω_o is 2 to 3.

The occupancy category can be input as I, II, III or IV. No other values are allowed. See ASCE 7-10 Section 11.5 for information about the occupancy category. The programs determine the occupancy importance factor, I, from the input occupancy category and ASCE 7-10 Table 1.5-1 and 1.5-2.

The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, S_s and S_1, as well as a long-period transition period, T_L. If seismic coefficients are user defined, specify S_s, S_1, T_L, F_a and F_v.

The site class can be A, B, C, D, or E. Note that site class F is not allowed for automatic ASCE 7-10 lateral seismic loads. See ASCE 7-10 Table 20.3-1 for site class definitions.

S_s is the mapped Risk-Targeted Maximum Considered Earthquake (MCE$_R$) spectral acceleration for short periods as determined in ASCE 7-10 Section 11.4.1. A typical range of values for S_s is 0 to 3. Note that the seismic maps show S_s in % g with a typical range of 0% to 300%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 125%g it should be input as 1.25g.

S_1 is the mapped MCE spectral acceleration for a one second period as determined in ASCE 7-10 Section 11.4.1. A typical range of values for S_1 is 0 to 1. Note that the seismic maps show S_1 in %g with a typical range of 0% to 100%. The input in the programs is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 100%g, it should be input as 1.0g.

F_a is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and S_s based on ASCE 7-10 Table 11.4-1. If site coefficients are user defined, the F_a is input directly by the user. A typical range of values for F_a is 0.8 to 2.5.

F_v is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and S_1 based on ASCE 7-10 Table 11.4-2. If site coefficients are user defined, F_v is input directly by the user. A typical range of values for F_v is 0.8 to 3.5.

T_L is the long-period transition period as determined in ASCE 7-10 Section 11.4.5.

2.14.3   Algorithm for 2012 IBC / ASCE 7-10 Seismic Loads

The algorithm for determining ASCE 7-10 seismic loads is based on ASCE 7-10 Section 12.8. A period is calculated as described in a preceding section entitled "Options for ASCE 7-10 Building Period."

The programs begin by calculating the design spectral response acceleration at short period, S_{DS}, using (ASCE 7-10 Eqs. 11.4-1 and 11.4-3).

$$S_{DS} = \frac{2}{3}F_a S_s \qquad \text{(ASCE 7-10 Eqns. 11.4-1 and 11.4-3)}$$

Next, the design spectral response acceleration is calculated at a one second period, S_{D1}, using (ASCE 7-10 Eqns. 11.4-2 and 11.4-3).

$$S_{D1} = \frac{2}{3}F_v S_1 \qquad \text{(ASCE 7-10 Eqns. 11.4-2 and 11.4-3)}$$

The programs determine a seismic design category (A, B, C, D, E, or F with A being the least severe and F being the most severe) based on ASCE 7-10 Section 11.6. A seismic design category is determined based on S_{DS} using ASCE 7-10 Table 11.6-1. A seismic design category also is determined based on S_{D1} using ASCE 7-10 Table 11.6-2. The more severe of the two seismic categories is chosen as the seismic design category for the building.

Initially a seismic response coefficient, C_s, is calculated using (ASCE 7-10 Eqn. 12.8-2). This base shear value is then checked against the limits speci-

fied in (ASCE 7-10 Eqns. 12.8-3, 12.8-4, 2.8-5, and 12.8-6) and modified as necessary to obtain the final base shear.

$$C_s = \frac{S_{DS}}{\dfrac{R}{I_e}}$$ (ASCE 7-10 Eqn. 12.8-2)

where,

S_{DS} = The design spectral response acceleration at short periods.

R = Response modification factor specified in ASCE 7-10 Table 12.2-1.

I_e = The occupancy importance factor determined in accordance with ASCE 7-10 Table 1.5-2.

The seismic response coefficient, C_s, need not exceed that specified in (ASCE 7-10 Eqns. 12.8-3 and 12.8-4). If the seismic response coefficient calculated in accordance with (ASCE 7-10 Eqns. 12.8-2) exceeds that calculated in accordance with (ASCE 7-10 Eqns. 12.8-3 and 12.8-4), the programs set the seismic response coefficient, C_s, equal to that calculated in accordance with (ASCE 7-10 Eqns. 12.8-3 and 12.8-4), as appropriate.

$$C_s = \frac{S_{D1}}{\left(\dfrac{R}{I_e}\right)T} \quad \text{for } T \le T_L$$ (ASCE 7-10 Eqn. 12.8-3)

$$C_s = \frac{S_{D1}\,T_L}{\left(\dfrac{R}{I_e}\right)T^2} \quad \text{for } T > T_L$$ (ASCE 7-10 Eqn. 12.8-4)

where,

S_{D1} = the design spectral response acceleration at a one second period

T = the building period used for calculating the base shear

T_L = the long-period transition period

and all other terms are as described for (ASCE 7-10 Eqn. 12.8-2).

C_s shall not be less than that shown in (ASCE 7-10 Eqn. 12.8-5).

$$C_s = 0.044 S_{DS} I_e \geq 0.01 \qquad \text{(ASCE 7-10 Eqn. 12.8-5)}$$

Finally, for structures located where S_1 is equal to or greater than 0.6g, C_s shall not be less than that shown in (ASCE 7-10 Eqn. 12.8-6).

$$C_s = \frac{0.5 S_1}{\left(\dfrac{R}{I_e} \right)} \qquad \text{(ASCE 7-10 Eqn. 12.8-6)}$$

where,

    S_1 = the mapped MCE_R spectral acceleration for a one second period

    and all other terms are as described for (ASCE 7-10 Eqn. 12.8-2).

The base shear, V, is calculated using (ASCE 7-10 Eqn. 12.8-1):

$$V = C_s W \qquad \text{(ASCE 7-10 Eqn. 12.8-1)}$$

    C_s = Seismic response coefficient as determined from one of (ASCE 7-10 Eqns. 12.8-2 through 12.8-6) as appropriate.

    W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (ASCE 7-10 Eqns. 12.8-11 and 12.8-12)

$$F_{story} = \frac{V \, w_{story} \, h_{story}^k}{\displaystyle\sum_{story=1}^{n} w_{story} \, h_{story}^k} \qquad \text{(ASCE 7-10 Eqns. 12.8-11 and 12.8-12)}$$

where,

    F_{story} = Portion of base shear applied to a story level.

    V = Building base shear.

    w_{story} = Weight of story level (based on specified mass).

    h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of k depends on the value of the building period, T, used for determining the base shear. If $T \leq 0.5$ seconds, $k = 1$. If $T \geq 2.5$ seconds, $k = 2$. If 0.5 seconds $< T < 2.5$ seconds, k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.15   1997 NEHRP Seismic Loads

2.15.1   Options for 1997 NEHRP Building Period

Three options are provided for the building period used in calculating the 1997 NEHRP automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the period based on (1997 NEHRP Eqn. 5.3.3.1-1). The value used for C_T is user input and h_n is determined by the programs from the input story level heights.

$$T_A = C_T \left(h_n \right)^{3/4} \qquad \text{(1997 NEHRP Eqn. 5.3.3.1-1)}$$

Note that C_T is always input in English units as specified in the code. A typical range of values for C_T is 0.020 to 0.035. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period also is calculated based on the (1997 NEHRP Eqn. 5.3.3.1-1). The value used for C_T is user input and h_n is determined from the input story level heights. Call this period T_A.

The programs also calculate a coefficient for the upper limit on the calculated period, C_u, based on 1997 NEHRP Table 5.3.3. Note that linear interpolation is used to calculate values of C_u where the value of S_{D1} is not specifically specified in Table 5.3.3.

The building period, T, that the programs choose is determined as follows:

- If $T_{\text{mode}} \leq C_u T_A$, then $T = T_{\text{mode}}$.

- If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it to $C_u T_A$. t is assumed that this comparison is performed before the period is specified.

2.15.2   Other Input Factors and Coefficients

The response modification coefficient, R, and the system overstrength factor, Ω, are direction dependent. Both are specified in 1997 NEHRP Table 5.2.2. A typical range of values for R is 2 to 8. A typical range of values for Ω is 2 to 3.

The seismic group can be input as I, II or III. No other values are allowed. See 1997 NEHRP Table 1.4 for information about the seismic group. An occupancy importance factor, I, is determined from the input seismic group and 1997 NEHRP Table 1.4.

The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, S_s and S_1. If seismic coefficients are user defined, specify S_s, S_1, F_a and F_v.

The site class can be A, B, C, D or E. Note that site class F is not allowed for the automatic 1997 NEHRP lateral seismic loads. See 1997 NEHRP Section 4.1.2.1 for site class definitions.

S_s is the mapped maximum considered spectral acceleration for short periods as determined in 1997 NEHRP Section 4.1.2. A typical range of values for S_s is 0 to 3. Note that the seismic maps show S_s in $\%g$ with a typical range of 0% to 300%. The input is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is $125\%g$, it should be input as $1.25g$.

S_1 is the mapped maximum considered spectral acceleration for a one second period as determined in 1997 NEHRP Section 4.1.2. A typical range of values for S_1 is 0 to 2. Note that the seismic maps show S_1 in %g with a typical range of 0% to 200%. The input is in g. Thus the map values should be divided by 100 when they are input. For example, if the map value is 125%g, it should be input as 1.25g.

F_a is a site coefficient. If the site coefficients are determined in accordance with code, the programs automatically determine F_a from the site class and S_s based on 1997 NEHRP Table 4.1.2.4a. If site coefficients are user defined, F_a is input directly by the user. A typical range of values for F_a is 0.8 to 2.5.

F_v is a site coefficient. If the site coefficients are determined in accordance with code, the programs automatically determine F_v from the site class and S_1 based on 1997 NEHRP Table 4.1.2.4b. If site coefficients are user defined, the F_v is input directly by the user. A typical range of values for F_v is 0.8 to 3.5.

2.15.3   Algorithm for 1997 NEHRP Seismic Loads

The algorithm for determining 1997 NEHRP seismic loads is based on 1997 NEHRP Section 5.3. A period is calculated as described in a preceding section entitled "Options for 1997 NEHRP Building Period."

The programs begin by calculating the design spectral response acceleration at short periods, S_{DS}, using 1997 NEHRP Eqns. 4.1.2.4-1 and 4.1.2.5-1.

$$S_{DS} = \frac{2}{3} F_a S_s \qquad \text{(1997 NEHRP Eqns. 4.1.2.4-1 and 4.1.2.5-1.)}$$

Next the programs calculate the design spectral response acceleration at a one second period, S_{D1}, using 1997 NEHRP Eqns. 4.1.2.4-2 and 4.1.2.5-2.

$$S_{D1} = \frac{2}{3} F_v S_1 \qquad \text{(1997 NEHRP Eqns. 4.1.2.4-2 and 4.1.2.5-2.)}$$

A seismic design category (A, B, C, D, E, or F with A being the least severe and F being the most severe) is determined based on 1997 NEHRP Section 4.2.1.A seismic design category is determined based on S_{DS} using 1997 NEHRP Table 4.2.1a. A seismic design category also is determined based on

S_{D1} using 1997 NEHRP Table 4.2.1b. The more severe of the two seismic categories is chosen as the seismic design category for the building.

Initially a seismic response coefficient, C_s, is calculated using (1997 NEHRP Eqn. 5.3.2.1-1). This base shear value is then checked against the limits specified in (1997 NEHRP Eqns. 5.3.2.1-2,5.3.2..1-2, and 5.3.2.1-3) and modified as necessary to obtain the final base shear.

$$C_s = \frac{S_{DS}}{\dfrac{R}{I}}$$ (1997 NEHRP Eqn. 5.3.2.1-1).

where,

S_{DS} = The design spectral response acceleration at short periods.

R = Response modification factor specified in 1997 NEHRP Table 5.2.2.

I = The occupancy importance factor determined in accordance with 1997 NEHRP Table 1.4.

The seismic response coefficient, C_s, need not exceed that specified in (1997 NEHRP Eqn. 5.3.2.1-2). If the seismic response coefficient calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-1) exceeds that calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-2), the programs set the seismic response coefficient, C_s, equal to that calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-2).

$$C_s = \frac{S_{D1}}{\left(\dfrac{R}{I}\right) T}$$ (1997 NEHRP Eqn. 5.3.2.1-2)

where,

S_{D1} = the design spectral response acceleration at a one second period

T = the building period used for calculating the base shear

and all other terms are as described for (1997 NEHRP Eqn. 5.3.2.1-1).

The seismic response coefficient, C_s, shall not be less than that specified in (1997 NEHRP Eqn. 5.3.2.1-3). If the seismic response coefficient calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-3) exceeds that calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-1), the programs set the seismic response coefficient equal to that calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-3).

$$C_s = 0.1 \, S_{D1} \, I \qquad\qquad \text{(1997 NEHRP Eqn. 5.3.2.1-3)}$$

where all terms are as previously described for (1997 NEHRP Eqns. 5.3.2.1-1 and 5.3.2.1-2).

Finally, if the building is in seismic design category E or F, the seismic response coefficient, C_s, shall not be less than that specified in (1997 NEHRP Eqn. 5.3.2.1-4). If the building is in seismic design category E or F and the seismic response coefficient calculated in accordance with (1997 NEHRP Eqn. 5.3.2.1-4) exceeds that calculated in accordance with (1997 NEHRP Eqns. 5.3.2.1-1 and 5.3.2.1-3), the programs set the seismic response coefficient equal to that calculated in accordance with (1997 NEHRP Eqn. 2-58.5.3.2.1-4).

$$C_s = \frac{0.5 S_1}{\dfrac{R}{I}} \qquad\qquad \text{(1997 NEHRP Eqn. 5.3.2.1-4)}$$

where,

S_1 = the mapped spectral acceleration for a one second period

and all other terms are as previously described for (1997 NEHRP Eqn. 5.3.2.1-1).

The base shear, V, is calculated using (1997 NEHRP Eqn. 5.3.2):

$$V = C_s W \qquad\qquad \text{(1997 NEHRP Eqn. 5.3.2)}$$

C_s = Seismic response coefficient as determined from one of (1997 NEHRP Eqns. 5.3.2.1-1 through 5.3.2.1-4) as appropriate.

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building by combining (1997 NEHRP Eqns. 5.3.4-1 and 5.3.4-2).

$$F_{story} = \frac{V \, w_{story} \, h_{story}^k}{\sum_{story=1}^{n} w_{story} \, h_{story}^k}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of k depends on the value of the building period, T, used for determining the base shear. If $T \leq 0.5$ second, $k = 1$. If $T \geq 2.5$ seconds, k = 2. If 0.5 second $< T < 2.5$ seconds, k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.16   2010 Chinese Seismic Loads

2.16.1   Options for 2010 Chinese Building Period

Two options are provided for the building period used in calculating the 2010 Chinese automatic seismic loads. They are as follows:

- **Program Calculated:** The programs use the longest period mode (fundamental) for the calculated time period. This period is T_1.

- **User Defined:** In this case, input a building period, which the programs use in the calculations.

2.16.2   Other Input Factors and Coefficients

The maximum value for seismic lateral influence factor, α_{max}, is used to calculate the factor of seismic lateral influence, α_1, obtained from the 2010 Chinese Design Code response spectrum for the fundamental period.

The seismic intensity, *SI*, has six possible values: 6(0.05g), 7(0.10g), 7(0.15g), 8(0.20g), 8(0.30g) and 9(0.40g).

The damping ratio, ζ, is used to adjust the shape of the response spectrum curve.

The characteristic ground period, T_g, is entered in units of seconds. The fundamental period, T_1, is multiplied by the period time discount factor, *PTDF*, prior to looking up the value of α_1 from the 2010 Chinese Design Code response spectrum curve. *PTDF* typically ranges from 0.5 to 1.0.

The enhancement factor is a multiplier to amplify the value or response spectrum curve.

2.16.3   Algorithm for 2010 Chinese Seismic Loads

The algorithm for determining 2010 Chinese seismic loads is based on calculating a factor of seismic lateral influence, α_1, from the response spectrum curve. The period used for determining this factor, T_1, is the fundamental period as described in a preceding section entitled "Options for 2010 Chinese Building Period."

The programs calculate the seismic lateral influence factor using (Eqn. 2-1).

$$\alpha_1 = \begin{cases} [0.45 + T(\eta_2 - 4.5)]\alpha_{max} & \text{If } T \le 0.1\text{s} \\ \eta_2 \alpha_{max} & \text{If } 0.1\text{s} < T < T_g \\ \left(\dfrac{T_g}{T}\right)^{\gamma} \eta_2 \alpha_{max} & \text{If } T_g < T \le 5T_g \\ [\eta_2 0.2^{\gamma} - \eta_1(T - 5T_g)]\alpha_{max} & \text{If } 5T_g < T \le 6T_g \end{cases} \qquad \text{(Eqn. 2-1)}$$

where,

α_1 = Seismic lateral influence factor.

α_{max} = Maximum value for the seismic lateral influence factor.

T = $PTDF (T_1)$

T_1 = Fundamental period of the structure.

T_g = Characteristic ground period.

$PTDF$ = Period time discount factor.

γ = $0.9 + \dfrac{0.05 - \zeta}{0.5 + 5\zeta}$ (GB50011-2010 Eqn. 5.1.5-1)

η_1 = $0.02 + \dfrac{(0.05 - \zeta)}{(4 + 32\zeta)}$ $(\eta_1 \geq 0)$ (GB50011-2010 Eqn. 5.1.5-2)

η_2 = $1 + \dfrac{0.05 - \zeta}{0.08 + 1.6\zeta}$ $(\eta_2 \geq 0.55)$ (GB50011-2010 Eqn. 5.1.5-3)

ζ = Damping ratio.

The total specified load for lateral seismic action, F_{Ek}, is calculated using (Eqn. 2-2):

$$F_{Ek} = \alpha_1 G_{Eq} \qquad \text{(GB50010-2010 Eqn. 5.2.1-1)}$$

where,

α_1 = Seismic lateral influence factor calculated in (Eqns. 2-1).

G_{Eq} = $0.85 G_E$, G_E is total representative gravity load of building.

The total specified load for lateral seismic action, F_{Ek}, is broken into a concentrated force applied to the top of the structure and forces applied at each story level in accordance with (Eqn. 2-2):

$$F_{Ek} = \Delta F_n + \sum_{i=1}^{n} F_i \qquad \text{(Eqn. 2-2)}$$

where,

F_{Ek} = Total specified load for lateral seismic action.

ΔF_n = Concentrated force at the top of the building.

F_i = Portion of total specified load applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the structure, ΔF_n, is calculated as::

$$\Delta F_n = \delta_n F_{Ek} \qquad\qquad \text{(GB50011 2010 Eqn. 5.2.1-3)}$$

where,

F_{Ek} = Total specified load for lateral seismic action.

$$\delta_n = \begin{cases} 0.08T_1 + 0.07 & \text{If } T_1 > 1.4T_g \text{ and } T_g \leq 0.35 \\ 0.08T_1 + 0.01 & \text{If } T_1 > 1.4T_g \text{ and } 0.35 < T_g \leq 0.55 \\ 0.08T_1 - 0.02 & \text{If } T_1 > 1.4T_g \text{ and } T_g \geq 0.55 \\ 0 & \text{If } T_g \leq 1.4T_g \end{cases}$$

The remaining portion of the lateral seismic load, $(F_{Ek} - \Delta F_n)$, is distributed over the height of the structure in accordance with:

$$F_i = \frac{G_i H_i}{\sum\limits_{j=1}^{n} G_j H_j} F_{Ek}\left(1 - \delta_n\right) \qquad\qquad \text{(GB50010 2010 Eqn.5.2.1-2)}$$

where,

F_i = Portion of lateral seismic load applied to story level i.

F_{Ek} = Total specified load for lateral seismic action.

ΔF_n = Concentrated force at the top of the structure.

G_i, G_j = Equivalent gravity load of lumped mass for story levels i and j, respectively.

H_i, H_j = Story heights of lumped masses i and j, respectively, measured from base of structure to story level.

n = Number of story levels in the structure.

2.17   2004 NZS 1170.5 Seismic Loads

2.17.1   Options for 2004 NZS 1170.5 Building Period

Two options are provided for the building period used in calculating the 2004 NZS automatic seismic loads. They are:

- **Program Calculated:** The programs use the longest period mode calculated to have the largest participation factor in the direction that loads are being calculated (*X* or *Y*). Call this period T_1.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against the program calculated period.

2.17.2   Other Input Factors and Coefficients

The structural performance factor, S_p, is based on Section 4.4 of the 2004 NZS 1170.5. A typical range of values for S_p is 0.7 to 1.0.

The structural ductility factor, μ, is based on Section 4.3 of the 2004 NZS 1170.5.

The site subsoil class can be A, B, C, D, or E. See 2004 NZS 1170.5 Subsection 3.1.3 for site subsoil class definitions. The site subsoil class in combination with the period, T_1, are used to look up the seismic hazard coefficient, $C_h(T_1)$, as described in Subsection 3.1.2 of the 2004 NZS 1170.5.

Z is the hazard factor as determined from Table 3.3 of the 2004 NZS 1170.5. A typical range of values for *Z* is 0.13 to 0.55.

R is the return period factor as determined from Table 3.5 of the 2004 NZS 1170.5. A typical range of values for *R* is 0.2 to 1.8, but should be limited such that *ZR* does not exceed 0.7.

D is the shortest distance (in kilometers) from the site to the nearest fault listed in Table 3.6. The distance, *D*, is used to compute the near-fault factor, $N(D,T)$, as given in Subsection 3.1.6.2 of the 2004 NZS 1170.5. A typical range of values for $N(D,T)$ is 1 to 1.72.

2.17.3   Algorithm for 2004 NZS 1170.5 Seismic Loads

The algorithm for determining 2004 NZS 1170.5 seismic loads is based on Section 6.2 of the 2004 NZS 1170.5 entitled "*Equivalent Static Method.*" A period is calculated as described in a preceding section entitled "Options for 2004 NZS 1170.5 Building Period."

The programs begin by calculating the elastic site hazard spectrum for horizontal loading, $C(T)$, using (NZS Eqn. 1170.5 3.1(1))

$$C(T_1) = C_h(T_1)ZR_u N(T,D) \qquad \text{(NZS Eqn. 1170.5 3.1(1))}$$

where,

$C_h(T_1)$ =   Seismic hazard coefficient for period T as determined by the program from Table 3.1 of the 2004 NZS 1170.5 Commentary.

Z =   The hazard factor determined from Clause 3.1.4 taking account of the limitation on the value of ZR_u given by Clause 3.1.1

R_u =   Return period factor.

$N(T,D)$ = Near-fault factor determined from clause 3.1.6.2.

$$N(T,D) = N_{max}(T) \quad \text{for } D \le 2\,\text{km}$$

$$= 1 + \left(N_{max}(T) - 1\right)\frac{20-D}{18} \quad \text{for } 2 < D \le 20\,\text{km}$$

$$= 1.0 \qquad\qquad\qquad \text{for } D > 20\,\text{km}$$

where,

D =   the shortest distance (in kilometers) from the site to the nearest fault listed in Table 3.6.

$N_{max}(T)$ = the maximum near-fault factor and is linearly interpolated for period T from Table 3.7.

Next, the horizontal design action coefficient is calculated at the T period, $C_d(T_1)$, using the following equation:

$$C_d(T_1) = \frac{C(T_1)S_p}{k_\mu} \geq \left(\frac{Z}{20} + 0.02\right)R_u \text{ but not less than } 0.03R_u \quad \text{(NZS Eqn. 5.2(1))}$$

where,

$C(T_1)$ =   elastic site hazard spectrum calculated in (NZS Eqn. 1170.5 3.1(1))

S_p =   structural performance factor

For soil Classes A, B, C and D

k_μ = μ for $T_1 \geq 0.7$ s

        = $\dfrac{(\mu-1)T_1}{0.7} + 1$ for $T_1 < 0.7$ s

For soil class E

k_μ = μ for $T_1 \geq 1$ s or $\mu < 1.5$

        = $(\mu-1)T_1 + 1.5$ for $T_1 < 1$ s and $\mu \geq 1.5$

provided that for the purposes of calculating k_μ, T_1 shall not be taken less than 0.4 s.

μ =   structural ductility factor

and for the purposes of calculating k_μ, T_1 shall not be taken less than 0.4 second for site subsoil classes A, B, and C; 0.6 second for site subsoil class D; or 1.0 second for site subsoil class E.

The horizontal base shear, V, is calculated using (NZS Eqn. 1170.5 6.2(1)):

$$V = C_d(T_1)W \quad\quad\quad\quad\quad\quad\quad\quad \text{(NZS Eqn. 1170.5 6.2(1))}$$

where,

$C_d(T_1)$ = Horizontal design action coefficient calculated in (NZS Eqn. 5.2(1))

W = Weight of the building (based on specified mass).

The horizontal base shear, V, is distributed over the height of the building in accordance with (NZS Eqn. 1170.5 6.2(2))

$$F_{story} = F_t + 0.92V \frac{w_{story}\,h_{story}}{\displaystyle\sum_{story=1}^{n} w_{story}\,h_{story}} \qquad \text{(NZS Eqn. 1170.5 6.2(2))}$$

where,

F_{story} = Portion of base shear applied to a story level.

F_t = $0.08V$ if story = top level
  or
F_t = 0 if story $\neq$ top level.

V = Horizontal base shear calculated in (NZS Eqn. 6.2(1)).

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

n = Number of story levels in the structure.

2.18   2007 AS 1170.4 Seismic Loads

2.18.1   Options for 2007 AS 1170.4 Building Period

Three options are provided for the building period used in calculating the 2007 AS 1170.4 automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the fundamental period based on (AS 1170.4 Eqn. 6.2(7)). The value used for h_n is determined by the programs from the input story level heights.

$$T_A = 1.25 k_t h_n^{0.75} \qquad \text{(AS 1170.4 Eqn. 6.2(7))}$$

where k_t is defined as follows (AS 1170.4 section 6.2.3):

k_t = 0.11 for moment-resisting steel frames

= 0.075 for moment-resisting concrete frames

= 0.06 for eccentrically braced steel frames

= 0.05 for all other structures

The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level and is input in meters.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}.

  The base shear obtained using a Program Calculated period cannot be less than 80% of the base shear obtained using the approximate period (AS 6.2.3).

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against T_A or T_{mode}. It is assumed that this comparison is performed before the period is specified.

2.18.2 Other Input Factors and Coefficients

The structural performance factor, S_p, is based on Section 6.5 of the 2007 AS 1170.4 and Table 6.5(A) and 6.5(B). A typical range of values for S_p is 0.67 to 1.0.

The structural ductility factor, μ, is based on Section 6.5 of the 2007 AS 1170.4 and Table 6.5(A) and 6.5(B). A typical range of values for μ is 2.0 to 3.0 (AS 2.2).

The site subsoil class can be A_e, B_e, C_e, D_e or E_e. See 2007 AS 1170.4 Subsection 4.1.1 for site subsoil class definitions. The site subsoil class in com-

bination with the period, T_1, are used to look up the spectral shape factor, $C_h(T_1)$, as described in Subsection 6.4 of the 2007 AS 1170.4.

Z is the hazard factor as determined from Table 3.2 of the 2007 AS 1170.4. A typical range of values for Z is 0.03 to 0. 29 (AS 2.2).

k_p is the return period factor as determined from Table 3.1 of the 2007 AS 1170.4. A typical range of values for k_p is 0.2 to 1.8.

2.18.3   Algorithm for 2007 AS 1170.4 Seismic Loads

The algorithm for determining 2007 AS 1170.4 seismic loads is based on Section 6.2 of the 2007 AS 1170.4 entitled "*Equivalent Static Analysis.*" A period is calculated as described in a preceding section entitled "Options for 2007 AS 1170.4 Building Period."

The programs begin by calculating the elastic site hazard spectrum for horizontal loading, $C(T)$, using (AS 1170.4 Eqn. 6.2(5))

$$C(T_1) = k_p Z C_h(T_1) \qquad \text{(AS Eqn. 1170.4 6.2(5))}$$

where,

$C_h(T_1)$ = Spectral shape factor for period T as determined by the program from Table 6.4 of the 2007 AS 1170.4.

k_p = Return period factor as given in AS 1170.4 clause 3.1.

Z = Hazard factor as given in AS 1170.4 clause 3.2.

S_p = Structural performance factor as given in AS 1170.4 clause 6.5.

μ = Structural ductility factor as given in AS 1170.4 clause 6.5.

The horizontal base shear, V, is calculated using (AS 1170.4 Eqn. 6.2(1)):

$$V \quad = \quad C_d(T_1)W \qquad \text{(AS 1170.4 Eqn. 6.2(1))}$$

where,

$C_d(T_1)$ = Horizontal design action coefficient calculated in (AS 1170.4 Eqn. 6.2(4))

$$C_d(T_1) = \frac{C(T_1)S_p}{\mu}$$ (AS 1170.4 Eqn. 6.2(4))

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (AS 1170.4 Eqn. 6.3(1)).

$$F_{story} = \frac{w_{story}\, h_{story}^{k}}{\sum\limits_{story=1}^{n} w_{story}\, h_{story}^{k}}\, V$$ (AS 1170.4 Eqn. 6.3(1))

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of k depends on the value of the building period, T, used for determining the base shear. If $T \leq 0.5$ second, $k = 1$. If $T \geq 2.5$ seconds, $k = 2$. If 0.5 second $< T < 2.5$ seconds, k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.19   2004 Eurocode 8 (EN 1998-1) Seismic Loads

2.19.1   Options for EN 1998-1:2004 Building Period

Three options are provided for the building period used in calculating the EN 1998-1:2004 automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the fundamental period based on (EN 1998-1 Eqn. 4.6). The value used for H is determined by the programs from the input story level heights.

$$T_1 = C_t H^{3/4} \qquad \text{(EN 1998-1 Eqn. 4.6)}$$

where C_t is defined as follows (EN 1998-1 section 4.3.3.2.2(3)):

$$C_t \quad = \quad 0.085 \text{ for moment-resisting steel frames}$$

$$= \quad 0.075 \text{ for moment-resisting concrete frames}$$

$$= \quad 0.075 \text{ for eccentrically braced steel frames}$$

$$= \quad 0.05 \text{ for all other structures}$$

The height H is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level and is input in meters.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against T_A or T_{mode}. It is assumed that this comparison is performed before the period is specified.

2.19.2   Other Input Factors and Coefficients

The spectral design spectrum, $S_d (T_1)$, is based on Section 3.2.2.5(4) of the EN 1998-1:2004 and Table 3.2 or Table 3.3.

The recommended choice of spectra is defined in EN 1998-1:2004 Section 3.2.2.2(2)P Table 3.2 and Table 3.3.

The behavior factor, q, is based on Section 3.2.2.5 of the EN 1998-1:2004 which is an approximation of the ratio of the seismic forces that the structure would experience if its response was completely elastic with 5% viscous damping, to the seismic forces that may be used in design, with a conventional elastic analysis model. A value for q is generally greater than 1.5.

The lower bound factor for horizontal design spectrum, β, is given in the National annex. The default value of β is 0.2.

The ground type can be A, B, C, D or E. See EN 1998-1:2004 Section 3.1.2 for site subsoil class definitions. The ground type in combination with the period, T_1, are used to look up the spectral design spectrum, $S_d(T_1)$, as described in Subsection 3.2.2.5 of the EN 1998-1:2004.

λ is the correction factor, the value of as λ is equal to 0.85 if $T_1 \leq 2T_c$ and the building has more than two stories, or $\lambda = 1.0$, otherwise.

2.19.3 Algorithm for EN 1998-1:2004 Seismic Loads

The algorithm for determining EN 1998-1:2004 seismic load is based on Section 4.3.3.2 of the EN 1998-1:2004 entitled "*Lateral Force Method of Analysis*." A period is calculated as described in a preceding section entitled "Options for EN 1998-1:2004 Building Period."

The programs begin by calculating the spectral design spectrum, $S_d (T_1)$ for horizontal loading based on Section 3.2.2.5(4) of the EN 1998-1:2004 and Table 3.2 or Table 3.3.

The horizontal base shear, F_b, is calculated using (EN 1998-1 Eqn. 4.5):

$$F_b = S_d (T_1) \ W \ \lambda \hspace{3cm} \text{(EN 1998-1 Eqn. 4.5)}$$

W = Weight of the building (based on specified mass)

λ = Correction factor.

The base shear, F_b, is distributed over the height of the building in accordance with (EN 1998-1 Eqn. 4.11).

$$F_{\text{story}} = \frac{w_{\text{story}} h_{\text{story}}}{\sum\limits_{\text{story}=1}^{n} w_{\text{story}} h_{\text{story}}} F_b \qquad \text{(EN 1998-1 Eqn. 4.11)}$$

where,

F_{story} =   Portion of base shear applied to a story level.

V =   Building base shear.

w_{story} =   Weight of story level (based on specified mass).

h_{story} =   Story height, distance from base of structure to story level.

n =   Number of story levels in the structure.

2.20   2002 Indian IS:1893

2.20.1   Options for 2002 Indian IS:1893 Building Period

Three options are provided for the building period used in calculating the IS:1893 automatic seismic loads. These are:

- **Approximate:** Calculate the approximate period, T_a, based on the formula discussed in Section 7.6.1 of IS:1893 Code. The period is calculated using following equations given in the IS:1893 code.

  $T_a = 0.075 h^{0.75}$ For RC framed buildings

  $T_a = 0.085 h^{0.75}$ For Steel framed buildings

  The height h is measured from the elevation of the specified bottom story/minimum elevation level to the (top of the) specified top story/maximum elevation level. The user should give the multiplier value as 0.075 or 0.085 in the static earthquake auto lateral load data form depending on the building type (viz. RC or steel) being modeled.

- **Program Calculated:** The program uses the period of the mode calculated to have the largest participation factor in the direction that

loads are being calculated (*X* or *Y*). The user must activate the dynamic analysis option to use the program calculated period for evaluation of seismic base shear. If no dynamic analysis option is defined, program assumes a period of 1 second to evaluate the seismic base shear.

- **User Defined:** In this case, input a building period, which the program will use in the calculations. For buildings with brick infill frames or shear walls, the user should calculate the period using the formula $T = 0.09h \big/ \left(\sqrt{d} \right)$, and this period should be given as input.

2.20.2 Other Input Factors and Coefficients

The seismic zone factor, Z, depends on the geographical location of the building as determined from Table 2, Section 6.4.2 of IS:1893. A typical range of values for Z is 0.10 to 0.36. As an alternative the user can also specify a user defined value of Z.

The response reduction factor *R* is input by the user. Typically *R* depends on the choice of lateral load resisting system, and it is specified in IS:1893 Table 7, Section 6.4.2. A typical range of values for *R* is 3 to 5 for RC and Steel buildings.

The soil profile type can be I, II or III. These correspond to soil types Rock or Hard Soil (type I), Medium Soil (type II) and Soft Soil (type III) respectively. No other values can be input.

The importance factor *I* is input by the user. Typically *I* depends on the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance, and it is specified in IS:1893 Table 6, Section 6.4.2.

2.20.3 Algorithm for IS:1893 Seismic Loads

The algorithm for determining IS:1893 seismic loads is based on Sections 6.4.2, 7.5.3 and 7.7 of IS:1893 code. A period is calculated as described in the previous section entitled Options for IS:1893 Building Period.

Next the value of seismic base shear is computed using the following expression.

$$V_b \quad = \quad A_h W \qquad \text{(IS:1893 Section.7.5.3)}$$

and A_h is given be the following equation:

$$A_h \quad = \quad ZIS_a/2Rg \qquad \text{(IS:1893 Section.6.4.2)}$$

where,

A_h = The design horizontal spectrum value

S_a/g = Spectral acceleration coefficient computed using expressions given in section 6.4.5 of IS:1893 for 5% damping

R = Response reduction factor.

I = Importance factor.

W = Seismic weight of the building (based on specified mass)

The base shear, V_b, is distributed over the height of the building in accordance with equation given in Section 7.7 of IS:1893.

$$Q_i = V_B \frac{W_i h_i^k}{\sum\limits_{i=1}^{n} W_i h_i^k} \qquad \text{(IS:1893 Section.7.7)}$$

where,

Q_i = Portion of base shear applied to i^{th} story level.

V_b = Base shear.

W_i = Weight of ith story level (based on specified mass).

h_i = i^{th} Story height, distance from base of building to story level.

k = 2

n = No. of stories in the building

Note: If the user wants to compute the seismic forces for a building with a damping ratio other than the default 5%, the corresponding multiplier for converting the default 5% spectral acceleration coefficient to another damping ratio should be taken from Table 3, Section 6.4.2 of IS:1893 and the multiplier should be multiplied by the zone factor *Z*; the resulting value should be given as the user-defined seismic zone factor in the static earthquake auto lateral load form.

2.21   2008 Italian NTC Seismic Loads

The algorithm for determining NTC 2008 seismic load is based on Section 7.3.3.2 of NTC 2008 entitled "*Analisi lineare statica*" (linear static analysis).

2.21.1   Options for 2008 Italian NTC Building Period

Three options are provided for the building period used in calculating the 2008 Italian NTC automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the period based on NTC 2008 Eq. 7.3.5). The value used for C_1 is user input, and H is determined by the programs from the input story level heights:

$$T_1 = C_1 \cdot H^{3/4} \qquad\qquad \text{(NTC 2008 Eq. 7.3.5)}$$

C_1 is a coefficient that depends on the structure material:
$C_1 = 0.085$ for steel frame structures
$= 0.075$ for concrete frame structures
$= 0.05$ for other types of structures

H is the total height of the structure measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (*X* or *Y*). Call this period T_{mode}.

- **User Defined:** In this case, input a building period, which the programs use in the calculations.

2.21.2   Other Input Factors and Coefficients

The parameters specified are Fundamental Parameters, a_g, F_0 and T_c^*, the spectrum type, the limit state, the soil type, the topography, the ratio for site altitude at the base of a hill to the height of the hill (h/H), the damping (ξ) for elastic spectrum and the behavior correction factor (q) for design spectrum, and a correction factor Lambda (λ) that is equal to 0.85 if the structure has at least 3 stories or more; otherwise Lambda (λ) is taken as 1. Lambda is a user input. Any positive, nonzero value can be specified for the Fundamental Parameters. The behavior factor must satisfy $q \geq 1.0$ (the program will accept any nonzero value). The subsoil type can be input as A, B, C, D or E. The topography type can be T1, T2, T3 or T4.

2.21.3   Algorithm for 2008 Italian NTC Seismic Loads

The Fundamental Parameters a_g (peak ground acceleration), F_0 (magnification factor), and T_c^* (reference period) can be entered based on a given set of Latitude and Longitude, by Island name or user specified. For the Latitude and Longitude and Island Name options, the user also needs to input the Limit State, the Usage Class, and the Nominal Life of the structure. These parameters are used for computing the Return period, T_R.

$$T_R = \frac{-V_R}{\ln\left(1 - P_{VR}\right)} \qquad \text{and,}$$

$$V_R = C_U V_N$$

where,

V_N = nominal life of the structure
C_U = usage coefficient

Usage Class	I	II	III	IV
Coefficient, C_U	0.7	1.0	1.5	2.0

The Limit State option can be SLO, SLD for elastic spectrum and SLV and SLC for design spectrum. The P_{VR} parameters are determined from the following table:

Spectrum Type	Limit State	$P_{VR \%}$	Description
Elastic	SLO	81	Immediate Occupancy
	SLD	63	Damage Control
Design	SLV	10	Life safety
	SLC	5	Collapse Prevention

For a given return period, T_R the parameters $a_g(T_R)$, $F_0(T_R)$ and $T_c^*(T_R)$, here called p, can be calculated as follows:

$$\log(p) = \log(p_1) + \log\left(\frac{p_2}{p_1}\right) \cdot \log\left(\frac{T_R}{T_{R1}}\right) \cdot \left[\log\left(\frac{T_{R2}}{T_{R1}}\right)\right]^{-1}$$

The ordinates of the response spectrum are calculated using the equations given below. The values of T_B, T_C, T_D, and S depend on the specified soil type and spectrum type.

2.21.3.1 Horizontal Elastic Response Spectrum

$$0 \leq T < T_B \quad S_e(T) = \frac{a_g}{g} S\eta F_0 \left[\frac{T}{T_B} + \frac{1}{\eta F_0}\left(1 - \frac{T}{T_B}\right)\right]$$

$$T_B \leq T < T_C \quad S_e(T) = \frac{a_g}{g} S\eta F_0$$

$$T_C \leq T < T_D \quad S_e(T) = \frac{a_g}{g} S\eta F_0 \left[\frac{T_C}{T}\right]$$

$$T_D \leq T \quad S_e(T) = \frac{a_g}{g} S\eta F_0 \left[\frac{T_C T_D}{T^2}\right]$$

$\eta = \sqrt{10/(5 + \xi)} \geq 0.55$, where ξ is damping in percentage

The S and spectra ordinate are based on the following equations:

$$S = S_s S_T$$

$$T_C = C_C T_C^{\ *}; \ T_B = \frac{T_C}{3}; \ T_D = 4\frac{a_g}{g} + 1.6$$

The parameter C_c, S_s and S_T are obtained using Soil Type and Topography.

Soil Type	S_s	C_c
A	1.00	1.00
B	$1.00 \le 1.40 - 0.40 F_0 \frac{a_g}{g} \le 1.20$	$1.10\left(T_c^*\right)^{-0.20}$
C	$1.00 \le 1.70 - 0.6 F_0 \frac{a_g}{g} \le 1.50$	$1.05\left(T_c^*\right)^{-0.33}$
D	$0.90 \le 2.40 - 1.5 F_0 \frac{a_g}{g} \le 1.80$	$1.25\left(T_c^*\right)^{-0.50}$
E	$1.00 \le 2.00 - 1.10 F_0 \frac{a_g}{g} \le 1.60$	$1.15\left(T_c^*\right)^{-0.40}$

Topography	S_T
T1	1.0
T2	$1.0 \le 1 + 0.2\frac{h}{H} \le 1.2$
T3	$1.0 \le 1 + 0.2\frac{h}{H} \le 1.2$
T4	$1.0 \le 1 + 0.4\frac{h}{H} \le 1.4$

2.21.3.2 Vertical Elastic Response Spectrum

$$0 \le T < T_B \quad S_{ve}(T) = \frac{a_g}{g} S \eta F_v \left[\frac{T}{T_B} + \frac{1}{\eta F_0}\left(1 - \frac{T}{T_B}\right) \right]$$

$$T_B \le T < T_C \quad S_{ve}(T) = \frac{a_g}{g} S \eta F_v$$

$$T_C \le T < T_D \quad S_{ve}(T) = \frac{a_g}{g} S \eta F_v \left[\frac{T_C}{T} \right]$$

$$T_D \leq T \quad S_{ve}(T) = \frac{a_g}{g} S \eta F_v \left[\frac{T_C T_D}{T^2} \right]$$

$\eta = \sqrt{10/(5+\xi)} \geq 0.55$, where ξ is damping in percent

$$S = S_s S_T$$

$$F_v = 1.35 F_0 \left(\frac{a_g}{g} \right)^{0.5}$$

Soil Type	S_s	T_B	T_C	T_D
A, B, C, D, E	1.00	0.05 s	0.15 s	1.0 s

Topography	S_T
T1	1.0
T2	1.2
T3	1.2
T4	1.4

2.21.3.3 Design Horizontal Response Spectrum

The Design Horizontal Spectrum is same as the Elastic Horizontal spectrum, with the exception of the following:

The η parameter for Design spectrum is defined as $\eta = 1/q_h$

where, q_h is the structure behavior factor for the horizontal component.

2.21.3.4 Design Vertical Response Spectrum

The Design Vertical Spectrum is same as Elastic Vertical spectrum, with the exception of the following:

The η parameter for Design spectrum is defined as $\eta = 1/q_v$

where, q_v is the structure behavior factor for the vertical component (1.5 for buildings, 1.0 for bridges).

The programs begin by calculating the spectral design spectrum, $S_d(T_1)$ for horizontal loading based on Section 3.2 of the NTC 2008.

The horizontal base shear, F_h, is calculated using:

$$F_h = S_d\left(T_1\right)W\frac{\lambda}{g} \qquad \text{(NTC § 7.3.3.2)}$$

$S_d(T_1)$ = spectral acceleration
W = weight of the building
λ = correction factor (user specified)
g = gravity acceleration

The base shear, F_h, is distributed over the height of the building in accordance with (NTC Eq. 7.3.6):

$$F_i = F_h\frac{z_iW_i}{\sum_{i=1}^{n}z_iW_i}$$

F_i = portion of the base shear applied at the story level
F_h = building base shear
z_i = story height, distance from base of structure to story level
W_i = weight of the story level (based on specified mass)
n = number of story levels in the structure

2.22   2007 Turkish Seismic Code (TSC) Loads

2.22.1   Options for 2007 TSC Building Period

Three options are provided for the building period used in calculating the 2007 TSC automatic seismic loads. They are:

- **Method A:** Calculate the approximate period, T_A, using section 2.7.4.2

$$T_A = 0.1N \qquad \text{(TSC Section 2.7.4.2)}$$

where,

N = The number of stories in the structure based on the specified top and bottom story levels.

Program Calculated: ETABS starts with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{ETABS}. ETABS also calculates a period based on the Method A. Call this period T_A. The building period, T, that ETABS chooses is given as:

If Number of Stories $\leq$ 13, then $T = T_{\text{ETABS}}$.

If Number of Stories > 13 and If $T_{\text{ETABS}} > 0.1N$, then $T = T_A$.

If Number of Stories > 13 and If $T_{\text{ETABS}} < 0.1N$, then $T = T_{\text{ETABS}}$.

User Defined: In this case the user inputs a building period. ETABS uses this period in the calculations. It does not compare it against the Method A period. It is assumed that this comparison is performed before the period is specified.

2.22.2 Other Input Factors and Coefficients

The seismic zone factor, Z, can be input in accordance with the code, which restricts it to one of the following values: 0.10, 0.2, 0.3, 0.4 as specified in 2007 TSC Table 2.2.

The seismic importance factor, I, can be input as any value. See 2007 TSC Table 2.3. A typical range of values for I is 1.0 to 1.5.

The local site classes for soil characteristics, Z, can be $Z1$, $Z2$, $Z3$ or $Z4$. These correspond to spectrum characteristic periods, T_A and T_B are given in 2007 TSC Table 2.4. No other values can be input.

The R factor is direction dependent. It is specified in 2007 TSC Table 2.5. A typical range of values for R is 4 to 8.

2.22.3   Algorithm for 2007 Turkish Seismic Code Loads

The algorithm for determining 2007 TSC seismic loads is based on Part II, Section 2.4 of the 2007 TSC. ETABS calculates a period as described in a preceding section entitled "Options for 2007 TSC Building Period."

The base shear, *V*, is calculated from the below equation.

$$V = \frac{A(T_1)}{R_a(T_1)} W \geq 0.10 A_0 I W \qquad \text{EDP 2007 Eqn. 2.4}$$

where,

$A(T_1)$ = Spectral Acceleration Coefficient corresponding to 5% elastic damping

$R_a(T_1)$ = Seismic Load Reduction Factor

W   = Weight of the building (based on specified mass)

The spectral acceleration coefficient $A(T_1)$ is computed using TSC 2007 Eqn. 2.1.

$$A(T_1) = A_0 I\ S(T_1) \qquad \text{EDP 2007 Eqn. 2.1}$$

where,

A_0 =   Effective ground acceleration coefficient corresponding to 5% elastic damping from 2007 TSC Table 2.2.

Seismic Zone	A_0
1	0.40
2	0.30
3	0.20
4	0.10

I   = Importance factor.

$S(T_1)$ = Spectral Coefficient determined from TSC 2007 Eqn. 2.2.

$$S(T_1) = 1 + 1.5\frac{T_1}{T_A} \qquad \text{for } 0 \le T_1 \le T_A$$

$$= 2.5 \qquad \text{for } T_A \le T_1 \le T_B \qquad \text{EDP 2007 Eqn. 2.2}$$

$$= 2.5\left(\frac{T_B}{T_1}\right)^{0.8} \qquad \text{for } T_B < T_1$$

Spectrum Characteristic Periods, T_A and T_B, are specified in 2007 TSC Table 2.4.

Local Site Class	T_A	T_B
Z1	0.10	0.30
Z2	0.15	0.40
Z3	0.15	0.60
Z4	0.20	0.90

R_a = Seismic Load Reduction Factor that is determine using 2007 TSC Eqn. 2.3.

$$R_a(T_1) = 1.5 + (R - 1.5)\frac{T}{T_A} \qquad \text{for } 0 \le T_1 \le T_A$$

$$R_a(T_1) = R \qquad \text{for } T_1 > T_A$$

Note that the weight, W, that ETABS uses is derived from the building mass.

The total base shear, V, is broken into a concentrated force applied to the top of the building and forces applied at each story level in accordance with the following equations:

$$V = F_N + \sum_{story=1}^{N} F_{story}$$

where,

V = Building base shear.

F_N = Concentrated force at the top of the building.

F_{story} = Portion of base shear applied to a story level.

n = Number of story levels in the building.

The concentrated force at the top of the building, F_N, is calculated as:

$$F_N = 0.0075NV$$

EDP 2007 Eqn. 2.8

where,

N = Number of story levels in the building.

V = Building base shear.

The remaining portion of the base shear, $(V - F_N)$, is distributed over the height of the building in accordance with the Equation (2007 TSC Equation 2.9):

$$F_{\text{story}} = \frac{(V - F_N)\, w_{\text{story}}\, h_{\text{story}}}{\displaystyle\sum_{\text{story}=1}^{N} w_{\text{story}}\, h_{\text{story}}}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

F_N = Concentrated force at the top of the building.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of building to story level.

2.23   2009 Korean Building Code (KBC) Seismic Loads

2.23.1   Options for 2009 KBC Building Period

Three options are provided for the building period used in calculating the 2009 KBC automatic seismic loads. They are as follows:

- **Approximate Period:** Calculate the period based on (KBC 2009 Eqn. 0306.5.5). The values used for C_t and x are user input, and h_n is determined by the programs from the input story level heights.

$$T_A = C_t \left(h_n \right)^{0.75} \qquad\qquad \text{(KBC 2009 Eqn. 0306.5.5)}$$

   Note that C_t is always input in Metric units, as specified in the code. A typical range of values for C_t is 0.049 to 0.085. The height h_n is measured from the elevation of the specified bottom story/minimum level to the (top of the) specified top story/maximum level in meters.

- **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y). Call this period T_{mode}. A period is also calculated based on (KBC 2009 Eqn. 0306.5.5). The values used for C_t is user input, and h_n is determined from the input story level heights. Call this period T_A.

   The programs also calculate a coefficient for the upper limit on the calculated period, C_u. The building period, T, that the programs choose is determined as follows:

   –   If $T_{\text{mode}} \leq C_u T_A$, then $T = T_{\text{mode}}$.

   –   If $T_{\text{mode}} > C_u T_A$, then $T = C_u T_A$.

- **User Defined:** In this case, input a building period, which the programs use in the calculations. They do not compare it against $C_u T_A$. It is assumed that this comparison is performed before the period is specified.

2.23.2   Other Input Factors and Coefficients

The response modification factor, R, and the system overstrength factor, Ω_o, are direction dependent. Both are specified in KBC 2009 Table 0306.6.1. A typical range of values for R is 1.5 to 8. A typical range of values for Ω_o is 2 to 3.

The programs determine the occupancy importance factor, I_E, from the input occupancy category and KBC 2009 Table 0306.4.1.

The seismic coefficients can be input in accordance with the code or they can be user defined. If the seismic coefficients are in accordance with code, specify a site class, S_s and S_1. If seismic coefficients are user defined, specify S_s, S_1, F_a and F_v.

The site class can be S_A, S_B, S_C, S_D, or S_E. See KBC 2009 Table 0306.3.2 for site class definitions.

S_s is the mapped maximum considered earthquake (MCE) spectral acceleration for short periods as determined in KBC 2009 Section 0306.3.1. A typical range of values for S_s is 0 to 0.55.

S_1 is the mapped MCE spectral acceleration for a one second period as determined in KBC 2009 Section 0306.3.3. A typical range of values for S_1 is 0 to 0.22.

F_a is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_a from the site class and S_s based on KBC 2009 Table 0306.3.3. A typical range of values for F_a is 0.8 to 2.5.

F_v is a site coefficient. If the site coefficients are determined in accordance with code, the software automatically determines F_v from the site class and S_1 based on KBC 2009 Table 0306.3.4. A typical range of values for F_v is 0.8 to 3.5.

2.23.3   Algorithm for 2009 KBC Seismic Loads

The algorithm for determining KBC 2009 seismic loads is based on KBC 2009 Section 0306. A period is calculated as described in a preceding section entitled "Options for KBC 2009 Building Period."

The programs begin by calculating the design spectral response acceleration at short period, S_{DS}, using (KBC 2009 Eqn. 0306.3.1).

$$S_{DS} = \frac{2}{3} F_a S_s \qquad \text{(KBC 2009 Eqn. 0306.3.1)}$$

Next, the design spectral response acceleration is calculated at a one second period, S_{D1}, using (KBC 2009 Eqn. 0306.3.2).

$$S_{D1} = \frac{2}{3} F_v S_1 \qquad \text{(KBC 2009 Eqn. 0306.3.2)}$$

The programs determine a seismic design category (A, B, C, or D with A being the least severe and D being the most severe) based on KBC 2009 Section 0306.4.3. A seismic design category is determined based on S_{DS} using KBC 2009 Table 0306.4.2. A seismic design category also is determined based on S_{D1} using KBC 2009 Table 0306.4.3. The more severe of the two seismic categories is chosen as the seismic design category for the building.

Initially a seismic response coefficient, C_s, is calculated using (KBC 2009 Eqn. 0306.5.2). This base shear value is then checked against the limits specified in (KBC 2009 Eqns. 0306.5.3, and 0306.5.4) and modified as necessary to obtain the final base shear.

$$C_s = \frac{S_{D1}}{\left[\dfrac{R}{I_E}\right]T} \qquad \text{(KBC 2009 Eqn. 0306.5.2)}$$

where,

S_{D1} = the design spectral response acceleration at a one second period.

R = Response modification factor specified in KBC 2009 Table 0306.6.1.

I_E = The occupancy importance factor determined in accordance with KBC 2009 Table 0306.4.1.

T = the building period used for calculating the base shear

The seismic response coefficient, C_s, need not exceed that specified in (KBC 2009 Eqns. 0306.5.3). If the seismic response coefficient calculated in accordance with (KBC 2009 Eqns. 0306.5.2) exceeds that calculated in accordance with (KBC 2009 Eqns. 0306.5.3), the programs set the seismic response coefficient, C_s, equal to that calculated in accordance with (KBC 2009 Eqns. 0306.5.3), as appropriate.

$$C_s = \frac{S_{DS}}{\left(\dfrac{R}{I_E}\right)}$$ (KBC 2009 Eqn. 0306.5.3)

where,

S_{DS} = The design spectral response acceleration at short periods.

and all other terms are as described for (KBC 2009 Eqn. 0306.5.2).

C_s shall not be less than that shown in (KBC 2009 Eqn. 0306.5.4).

$$C_s = 0.01$$ (KBC 2009 Eqn. 0306.5.4)

The base shear, V, is calculated using (KBC 2009 Eqn. 0306.5.8):

$$V = C_s W$$ (KBC 2009 Eqn. 0306.5.8)

C_s = Seismic response coefficient as determined from one of (KBC 2009 Eqns. 0306.5.2 through 0306.5.4) as appropriate.

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (KBC 2009 Eqn. 0306.5.9)

$$F_{story} = \frac{V\, w_{story}\, h_{story}^k}{\displaystyle\sum_{story=1}^{n} w_{story}\, h_{story}^k}$$ (KBC 2009 Eqn. 0306.5.9)

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = Exponent applied to building height. The value of k depends on the value of the building period, T, used for determining the base shear. If $T \leq 0.5$ seconds, $k = 1$. If $T \geq 2.5$ seconds, $k = 2$. If 0.5 seconds $< T < 2.5$ seconds, k is linearly interpolated between 1 and 2.

n = Number of story levels in the structure.

2.24   2011 Dominican Republic R-001 Seismic Loads

2.24.1   Options for 2011 Dominican Republic R-001 Seismic Building Period

Two options are provided for the building period used in calculating the 2011 R-001 automatic seismic loads. They are as follows:

▪ **Program Calculated:** The programs start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (*X* or *Y*).

▪ **User Defined:** In this case, input a building period, which the programs use in the calculations.

2.24.2   Other Input Factors and Coefficients

The response modification factor, *Rd*, is direction dependent. Rd is specified in 2011 R-001 Table 8. A typical range of values for *R* is 2 to 5.5.

The seismic coefficients can be input by user. The seismic coefficients are in S_s, S_1, F_a and F_v.

S_s is the mapped spectral acceleration for short periods as determined in 2011 R-001 Table 1. S_s is 1.55g for Zone I and 0.95g for Zone II. The input in the programs is in g.

S_1 is the mapped spectral acceleration for a one second period as determined in 2011 R-001 Table 1. S_1 is 0.75 g for Zone I and 0.55g for Zone II. The input in the programs is in g.

F_a is a site coefficient for short period as determined in 2011 R-001 Table 4. Site coefficients are user defined, F_a is input directly by the user. A typical range of values for F_a is 0.8 to 2.3.

F_v is a site coefficient for long period as determined in 2011 R-001 Table 5. Site coefficients are user defined, F_v is input directly by the user. A typical range of values for F_v is 0.8 to 3.2.

U is a use coefficient as determined in 2011 R-001 Table 7. Use coefficient is user defined, U is input directly by the user. A typical range of values for U is 0.9 to 1.50.

2.24.3   Algorithm for 2011 Dominican Republic R-001 Seismic Loads

The algorithm for determining 2011 Dominican Republic R-001 seismic loads is based on 2011 R-001 Section 34. A period is calculated as described in a preceding section entitled "Options for 2011 Dominican Republic R-001 Building Period."

The programs begin by calculating the design spectral response acceleration at short periods, S_{DS}.

$$S_{DS} = \frac{2}{3} F_a S_s$$

Next, the design spectral response acceleration is calculated at a one second period, S_{D1}.

$$S_{D1} = \frac{2}{3} F_v S_1$$

The programs determine T_0 and T_s.

$$T_0 = 0.2 \frac{S_{D1}}{S_{DS}} \text{, and}$$

$$T_s = 5T_0$$

The spectral acceleration ($S_a(T)$) at building period T is determined based on the expressions:

$$S_a(T) = \begin{cases} 0.6 \dfrac{S_{DS}}{T_0} T + 0.4 S_{DS} & \text{if} & T \leq T_0 \\ S_{DS} & \text{if} & T_0 < T \leq T_s \\ \dfrac{S_{D1}}{T} & \text{if} & T > T_s \end{cases},$$

Initially a seismic response coefficient, C_s, is calculated using Article 35. This base shear value is then checked against the limits specified.

$$C_s = \frac{U \bullet S_a(T)}{Rd} \geq 0.03$$

The base shear, V, is calculated using Article 39.

$$V = C_s W$$

C_s = Seismic response coefficient as determined.

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (Article 44).

$$F_{story} = \frac{V \, w_{story} \, h_{story}}{\displaystyle\sum_{story=1}^{n} w_{story} \, h_{story}}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

n = Number of story levels in the structure.

2.25 User Defined Seismic Loads

2.25.1 Input Factors and Coefficients

The base shear coefficient, C, is direction dependent. This coefficient multiplied times the building weight gives the lateral seismic base shear in the direction specified.

The building height exponent, k, is used as an exponent on the building height when determining the distribution of the base shear over the height of the building.

2.25.2 Algorithm for User Defined Seismic Loads

The base shear, V, is calculated using (Eqn. 2-6):

$$V = C\,W \tag{Eqn. 2-6}$$

where,

C = User-defined base shear coefficient.

W = Weight of the building (based on specified mass).

The base shear, V, is distributed over the height of the building in accordance with (Eqn. 2-7):

$$F_{story} = \frac{V \ w_{story} \ h_{story}^k}{\displaystyle\sum_{story=1}^{n} w_{story} \ h_{story}^k} \qquad\qquad \text{(Eqn. 2-7)}$$

where,

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of structure to story level.

k = A user-defined exponent.

n = Number of story levels in the structure.

2.26   Response Spectrum Functions

A response spectrum function is simply a list of period versus spectral acceleration values. In the programs, the acceleration values in the function are assumed to be normalized; that is, the functions themselves are not assumed to have units. Instead, the units are associated with a scale factor that multiplies the function and is specified when the response spectrum case is defined.

Response spectra can be defined in the programs from a text file (From File), from user specified parameters (User), and based on one of several built-in code response spectra.

2.26.1   From File

A response spectrum definition can be added from a text file. The text file should have period and spectral acceleration values. One set of values (period and spectral acceleration) should be provided on each line. Any line that has a $ symbol in the first character space is treated as a comment line and ignored. Any number of header lines at the beginning of the file can be speci-

fied to be ignored by the program. Those header lines do not need $ symbols at the beginning of them. The program quits reading the file when it reaches the end of the file or when it reaches a blank line. Note that the program considers a line with the first character space blank, the second character space a $ symbol and anything beyond the $ symbol as a blank line.

Typically the program does not import the file into its database. It simply maintains a link to the file location. Thus, if the response spectrum file is moved, or if the .model file is moved to another location, the program may suddenly be unable to locate the response spectrum file. If the response spectrum based on a text file is converted to a user-defined response spectrum, the program imports the response spectrum into its database file and the data will always be available to the model.

The program reads the response spectrum function file as follows:

o First it skips the specified number of header lines specified by the user.

o Next it checks to see if a line has a $ symbol as the first character. If it does, then it skips to the next line.

o If there is not a $ symbol as the first character on the line, the program reads the information on the line.

o If the line is blank or if the end of the file is reached, the program stops reading and closes the file.

2.26.2   User

When defining a User Spectrum, the period and spectral acceleration values are input for the function by the user.

2.26.3   Code Specific

The program allows definition of code specific response spectrum functions for a variety of building codes. The user can apply the program defaults or specify the parameters that define the code specific response spectrum. These parameters vary from code to code. The parameters specified for each of the codes included in the program are identified in sections that follow.

2.26.4   1994 UBC Parameters for a Response Spectrum Function

The 1994 UBC response spectrum function is based on Figure 16-3 in Chapter 16 of the 1994 UBC. The digitization of these response spectra is based on Section C106.2.1 in the 1996 SEAOC Recommended Lateral Force Requirements and Commentary (more commonly called the SEAOC Blue Book).

The parameters required are a seismic zone factor, Z and a soil type. Any positive, nonzero value can be specified for the seismic zone factor; see Table 16-I in the 1994 UBC for typical values. The soil type can be input as 1, 2 or 3; see Table 16-J in the 1994 UBC for typical values.

2.26.5   1997 UBC Parameters for a Response Spectrum Function

The 1997 UBC response spectrum function is constructed as shown in Figure 16-3 in Chapter 16 of the 1997 UBC. The parameters required are seismic coefficients C_a and C_v. Any positive, nonzero value can be specified for the seismic coefficients. See Tables 16-Q and 16-R in the 1997 UBC for typical values of these coefficients.

2.26.6   1996 BOCA Parameters for a Response Spectrum Function

The following parameters are input for the 1996 BOCA response spectrum function. Any positive, nonzero value can be input for these parameters.

A_a = Seismic coefficient representing the effective peak acceleration as determined in 1996 BOCA Section 1610.1.3.

A_v = Seismic coefficient representing the effective peak velocity-related acceleration as determined in 1996 BOCA Section 1610.1.3.

R = The response modification factor determined from 1996 BOCA Table 1610.3.3.

S =   The coefficient for the soil profile characteristics of the site as determined by 1996 BOCA Table 1610.3.1.

The 1996 BOCA response spectrum function is based on 1996 BOCA Section 1610.5.5. The response spectrum is constructed by plotting the modal seismic design coefficient, C_{sm}, versus the modal period of vibration, T_m. For a given period, T_m, the value of C_{sm} is determined using (Eqn. 11-3).

$$C_{sm} = \frac{1.2A_vS}{RT_m^{2/3}} \leq \frac{2.5A_a}{R} \qquad \text{(Eqn. 11-3)}$$

2.26.7 1995 NBCC Parameters for a Response Spectrum Function

The following parameters are input for the 1995 NBCC (Canadian) response spectrum function.

v =   Zonal velocity ratio.

Z_a =   Acceleration-related seismic zone.

Z_v =   Velocity-related seismic zone.

Values for these parameters can be found in Appendix C of the 1995 NBCC. Any positive, nonzero value can be input for the zonal velocity ratio, v. Any positive integer, or zero, can be input for the acceleration and velocity-related seismic zones.

The 1995 NBCC response spectrum function is based on item 44(a) in Commentary J of the 1995 NBCC.

2.26.8 2005 NBCC Parameters for a Response Spectrum Function

The following parameters are input for the 2005 NBCC (Canadian) response spectrum function.

Peak Ground Acceleration (PGA)

$S_a(0.20)$ = Spectral Acceleration at 0.2 Sec.

$S_a(0.50)$ = Spectral Acceleration at 0.5 Sec.

$S_a(1.0)$ = Spectral Acceleration at 1.0 Sec.

$S_a(2.0)$ = Spectral Acceleration at 2.0 Secs.

Site Class = A to F.

Values for these parameters can be found in Appendix C of the 2005 NBCC. Any positive, nonzero value can be input for the peak ground acceleration, *PGA*. Any positive integer, or zero, can be input for the spectral acceleration.

The 2005 NBCC response spectrum function is based on item 72 in Commentary J of the 2005 NBCC.

2.26.9   2010 NBCC Parameters for a Response Spectrum Function

The following parameters are input for the 2010 NBCC (Canadian) response spectrum function.

Peak Ground Acceleration (PGA)

$S_a(0.20)$ = Spectral Acceleration at 0.2 Sec.

$S_a(0.50)$ = Spectral Acceleration at 0.5 Sec.

$S_a(1.0)$ = Spectral Acceleration at 1.0 Sec.

$S_a(2.0)$ = Spectral Acceleration at 2.0 Secs.

Site Class = A to F.

Values for these parameters can be found in Appendix C of the 2010 NBCC. Any positive, nonzero value can be input for the peak ground acceleration, *PGA*. Any positive integer, or zero, can be input for the spectral acceleration.

The 2010 NBCC response spectrum function is based on item 4.1.8.4(7) Part 4 of Division B of the 2010 NBCC.

2.26.10   2015 NBCC Parameters for a Response Spectrum Function

The following parameters are input for the 2015 NBCC (Canadian) response spectrum function.

Peak Ground Acceleration (PGA)

$S_a(0.20)$ = Spectral Acceleration at 0.2 Sec.

$S_a(0.50)$ = Spectral Acceleration at 0.5 Sec.

$S_a(1.0)$ = Spectral Acceleration at 1.0 Sec.

$S_a(2.0)$ = Spectral Acceleration at 2.0 Secs.

$S_a(5.0)$ = Spectral Acceleration at 5.0 Secs.

$S_a(10.0)$ = Spectral Acceleration at 10.0 Secs.

Site Class = A to F.

Values for these parameters can be found in Appendix C of the 2010 NBCC. Any positive, nonzero value can be input for the peak ground acceleration, *PGA*. Any positive integer, or zero, can be input for the spectral acceleration.

For Site Class F, additional parameters i.e., F(0.20), F(0.50), F(1.0), F(2.0), F(5.0 and F(10.0) are also required user input.

The 2015 NBCC response spectrum function is based on item 4.1.8.4(7) Part 4 of Division B of the 2015 NBCC.

2.26.11   2003 IBC/ASCE 7-02 Parameters for a Response Spectrum Function

The following parameters are input for the 2003 IBC response spectrum function. Any positive, nonzero value can be input for these parameters.

S_{DS} = The 5% damped design spectral response acceleration at short periods as specified in 2003 IBC Section 1615.1.3.

S_{D1} = The 5% damped design spectral response acceleration at a one second period as specified in 2003 IBC Section 1615.1.3.

The 2003 IBC response spectrum function is based on the procedure described in 2003 IBC Section 1615.1.4.

2.26.12   2006 IBC/ASCE 7-05 Parameters for a Response Spectrum Function

The following parameters are input for the 2006 IBC response spectrum function. Any positive, nonzero value can be input for these parameters.

S_S = The 5% damped design spectral response acceleration at short periods as specified in 2006 IBC Section 1613.5.1 (ASCE 7-05 11.4.1).

S_1 = The 5% damped design spectral response acceleration at a one second period as specified in 2006 IBC Section 1613.5.1 (ASCE 7-05 11.4.1).

T_L = Long-Period transition period(s) as specified in ASCE 7-05 11.4.5.

Site Class = Site class A to F as specified in IBC 2006 Section 1613.5.2 (ASCE 7-05 11.4.2).

The IBC 2006 response spectrum function is based on the procedure described in IBC 2006 Section 1613.2.1.4 (ASCE 7-05 11.4).

2.26.13   2009 IBC/ASCE 7-05 Parameters for a Response Spectrum Function

The following parameters are input for the 2009 IBC response spectrum function. Any positive, nonzero value can be input for these parameters.

S_S = The 5% damped design spectral response acceleration at short periods as specified in 2009 IBC Section 1613.5.1 (ASCE 7-05 11.4.1).

S_1 =   The 5% damped design spectral response acceleration at a one second period as specified in 2009 IBC Section 1613.5.1 (ASCE 7-05 11.4.1).

T_L =   Long-Period transition period(s) as specified in ASCE 7-05 11.4.5.

Site Class = Site class A to F as specified in 2009 IBC Section 1613.5.2 (ASCE 7-05 11.4.2).

The 2009 IBC response spectrum function is based on the procedure described in 2009 IBC Section 1613.2.1.4 (ASCE 7-05 11.4).

2.26.14   2012 IBC/ASCE 7-10 Parameters for a Response Spectrum Function

The following parameters are input for the 2012 IBC response spectrum function. Any positive, nonzero value can be input for these parameters.

S_S = The 5% damped design spectral response acceleration at short periods as specified in IBC 2012 Section 1613.3.1 (ASCE 7-10 11.4.1).

S_1 = The 5% damped design spectral response acceleration at a one second period as specified in IBC 2012 Section 1613.3.1 (ASCE 7-10 11.4.1).

T_L = Long-Period transition period(s) as specified in ASCE 7-10 11.4.5.

Site Class = Site class A to F as specified in IBC 2012 Section 1613.3.2 (ASCE 7-10 11.4.2).

The IBC 2012 response spectrum function is based on the procedure described in IBC 2012 Section 1613.3 (ASCE 7-10 11.4).

2.26.15   1997 NEHRP Parameters for a Response Spectrum Function

The following parameters are input for the 1997 NEHRP response spectrum function. Any positive, nonzero value can be input for these parameters.

S_{DS} = The design earthquake spectral response acceleration at short periods as specified in (1997 NEHRP Eqn. 4.1.2.5-1).

S_{D1} = The design earthquake spectral response acceleration at a one second period as specified in (1997 NEHRP Eqn. 4.1.2.5-2).

The 1997 NEHRP response spectrum function is based on the procedure described in 1997 NEHRP Section 4.1.2.6.

2.26.16   1998 Eurocode 8 Parameters for a Response Spectrum Function

The 1998 Eurocode 8 response spectrum function is constructed as described in 1998 Eurocode ENV 1998-1-1:1994 Section 4.2.2. The parameters to be entered are the design ground acceleration, a_g, the subsoil class and the damping correction factor, η. Any positive, nonzero value can be specified for the design ground acceleration. The damping correction factor must satisfy $\eta \geq 0.7$. The subsoil class can be input as A, B, or C.

The ordinates of the response spectrum are calculated using Eqns. 4.1 through 4.4 in 1998 Eurocode ENV 1998-1-1:1994 Section 4.2.2. The values of β_o, T_B, T_C, T_D, k_1, k_2, and S are taken from Table 4.1 in 1998 Eurocode ENV 1998-1-1:1994 Section 4.2.2. Note that the value of these items depends on the specified subsoil class.

2.26.17   2004 Eurocode 8 Parameters for a Response Spectrum Function

The 2004 Eurocode 8 response spectrum function is constructed as described in EN 1998-1-1:2004 Section 3.2.2.5. The parameters to be entered are the design spectrum type, the ground type, the lower bound factor for the horizontal design spectrum, β and the behavior correction factor, q. Any positive,

nonzero value can be specified for the design ground acceleration. The behavior factor must satisfy $q \geq 1.5$ (the program will accept any nonzero value). The subsoil class can be input as A, B, C, D or E.

The ordinates of the response spectrum are calculated using Eqns. 3.13 through 3.16 in EN 1998-1-1:2004 Section 3.2.2.5. The values of T_B, T_C, T_D, and S are taken from Table 3.2 or 3.3 in 1998 Eurocode EN 1998-1-1:2004 Section 3.2.2.5. Note that the value of these items depends on the specified ground type and spectrum type.

2.26.18   1992 NZS 4203 Parameters for a Response Spectrum Function

For the 1992 NZS 4203 (New Zealand) response spectrum function, input a scaling factor and a site subsoil category. Any positive, nonzero value can be specified for the scaling factor. The site subsoil category can be input as A, B, or C.

The 1992 NZS 4203 (New Zealand) response spectrum function is constructed as specified in 1992 NZS 4203 Section 4.6.

The ordinates of the response spectrum are calculated using (1992 NZS4203 Eqns. 4.6.3 and 4.6.4). If (1992 NZS4203 Eqn. 4.6.3) is used, input the scaling factor as $(S_p)(R)(Z)(L_s)$. If (1992 NZS4203 Eqn. 4.6.4) is used, input the scaling factor as $(S_m)(S_p)(R)(Z)(L_u)$.

The program calculates the $C_h(T, 1)$ term in (1992 NZS4203 Eqns. 4.6.3 and 4.6.4) based on the input site subsoil category and the values for $\mu = 1.0$ in Figures 4.6.1a, b, and c and in Tables 4.6.1a, b, and c. In Table 4.6.1a the coefficient values for periods of 0, 0.09, and 0.20 second are taken as 0.40, 0.68, and 0.68, respectively. In Table 4.6.1b the coefficient values for periods of 0, 0.13, and 0.20 second are taken as 0.42, 0.80 and 0.80, respectively. In Table 4.6.1c the coefficient values for periods of 0 and 0.10 second are taken as 0.42 and 0.72, respectively.

2.26.19   2004 NZS 1170.5 Parameters for a Response Spectrum Function

For the 2004 NZS 1170.5 (New Zealand) response spectrum function, the following parameters are input. Any positive, nonzero value can be input for these parameters.

Site Class = Site class A to E as specified in NZS 1170.5 clause 3.1.3.

Z = The hazard factor determined from NZS 1170.5 clause 3.1.4.

R = The return period factor R_s or R_u for the appropriate limit state determined from NZS 1170.5 clause 3.1.5 but limited such that ZR_u does not exceed 0.7.

D = D is the shortest distance (in kilometers) from the site to the nearest fault listed in Table 3.6. The distance, D, is used to compute the near-fault factor, $N(D,T)$, as given in Subsection 3.1.6.2 of the 2004 NZS 1170.5. A typical range of values for $N(D,T)$ is 1 to 1.72.

$C_h(T)$ = The spectral shape factor determined from NZS 1170.5 clause 3.1.2 and Table 3.1 (computed by the program computed based on time period).

The NZS 1170.5:2004 response spectrum function is constructed as specified in NZS 1170.5:2004 Section 3.1.1.

2.26.20   2007 AS 1170.4 Parameters for a Response Spectrum Function

For the 2007 AS 1170.4 (Australia) response spectrum function, the following parameters are input. Any positive, nonzero value can be input for these parameters.

$C_h(T)$ = Spectral shape factor for period T as determined by the program from Table 6.4 of the AS 1170.4.

k_p = Return period factor as determined for AS 1170.4 clause 3.1.

Z = Hazard factor as determined for AS 1170.4 clause 3.2.

Site Class = Site class A_e to E_e as specified in AS 1170.4 clause 4.1.

S_p = Structural performance factor as given in AS 1170.4 clause 6.5.

μ = Structural ductility factor as given in AS 1170.4 clause 6.5.

The AS 1170.4:2007 response spectrum function is constructed as specified in AS 1170.4:2007 clause 7.2(a).

2.26.21   2007 AASHTO Parameters for a Response Spectrum Function

The AASHTO 2007 ground motion design spectra in CSiBridge is developed in accordance with the AASHTO Guide Specifications for LRFD Seismic Bridge Design. The design spectra uses the digitized USGS maps developed for AASHTO. Those maps were developed for a hazard of 7% probability of exceedance in 75 years (1000 return period).

The following parameters are input for the AASHTO 2007 response spectrum function. Any positive, nonzero value can be input for these parameters.

S_S = 0.2-Sec period spectral acceleration coefficient on Class B rock.

S_1 = 1.0-Sec period spectral acceleration coefficient on Class B rock.

Site Class = Site class A to F as specified in Section 3.4.2.1 and Table 1.

The AASHTO 2007 response spectrum function is based on the procedure described in AASHTO Guide Specifications for LRFD Seismic Bridge Design, Section 3.4.1.

2.26.22   2012 AASHTO Parameters for a Response Spectrum Function

The AASHTO 2012 ground motion design spectra in CSiBridge is developed in accordance with the AASHTO Guide Specifications for LRFD Seismic Bridge Design. The design spectra uses the digitized USGS maps developed for AASHTO. Those maps were developed for a hazard of 7% probability of exceedance in 75 years (1000 return period).

The following parameters are input for the AASHTO 2012 response spectrum function. Any positive, nonzero value can be input for these parameters.

S_S = 0.2-Sec period spectral acceleration coefficient on Class B rock.

S_1 = 1.0-Sec period spectral acceleration coefficient on Class B rock.

Site Class = Site class A to F as specified in Section 3.4.2.1 and Table 1.

The AASHTO 2012 response spectrum function is based on the procedure described in AASHTO Guide Specifications for LRFD Seismic Bridge Design, Section 3.10.2.1.

2.26.23   2002 Indian IS:1893 Response Spectrum Function

The IS:1893 response spectrum function is based on Figure 2 in section 6.4.5 of the IS:1893 code. The digitization of these response spectra is based on section 6.4.5.

The parameters required are a seismic zone factor *Z,* soil type and the damping ratio of the building structure. These values can be selected from relevant sections of the IS:1893 code.

2.26.24   2008 Italian NTC Parameters for a Response Spectrum Function

The 2008 Italian NTC response spectrum function is constructed as described in Technical Rules for Construction (NTC 2008). The parameters to be entered are Fundamental Parameters, a_g, F_0 and T_c^*, the spectrum type, the limit state, the soil type, the topography, the ratio for site altitude at base of hill to height of hill (h/H), the damping (ξ) for elastic spectrum and the behavior correction factor (q) for design spectrum. Any positive, nonzero value can be specified for the Fundamental Parameters. The behavior factor must satisfy $q \geq 1.0$ (the program will accept any nonzero value). The subsoil type can be input as A, B, C, D or E. The topography type can be T1, T2, T3 or T4.

The Fundamental Parameters a_g (peak ground acceleration), F_0 (magnification factor) and T_c^* (reference period), can be entered based on a given set of Latitude and Longitude, by Island name or user specified. For Latitude and Longitude and Island Name options, user also need to input the Limit State, the Usage Class and the Nominal Life of the structure. These parameters are used for computing Return period, T_R.

$$T_R = \frac{-V_R}{\ln\left(1 - P_{VR}\right)} \qquad \text{and,}$$

$$V_R = C_U V_N$$

where,

V_N = nominal life of the structure
C_U = usage coefficient

Usage Class	I	II	III	IV
Coefficient, C_U	0.7	1.0	1.5	2.0

The Limit State option can be SLO, SLD for elastic spectrum and SLV and SLC for design spectrum. The P_{VR} parameters are determined from the following table:

Spectrum Type	Limit State	P_{VR} %	Description
Elastic	SLO	81	Immediate Occupancy
	SLD	63	Damage Control
Design	SLV	10	Life safety
	SLC	5	Collapse Prevention

For a given return period, T_R the parameters $a_g(T_R)$, $F_0(T_R)$ and $T_c*(T_R)$, here called p, can be calculated as follows:

$$\log(p) = \log(p_1) + \log\left(\frac{p_2}{p_1}\right) \cdot \log\left(\frac{T_R}{T_{R1}}\right) \cdot \left[\log\left(\frac{T_{R2}}{T_{R1}}\right)\right]^{-1}$$

The ordinates of the response spectrum are calculated using the equations given below. The values of T_B, T_C, T_D, and S depend on the specified soil type and spectrum type.

2.26.24.1 Horizontal Elastic Response Spectrum

$$0 \leq T < T_B \quad S_e(T) = \frac{a_g}{g} S \eta F_0 \left[\frac{T}{T_B} + \frac{1}{\eta F_0} \left(1 - \frac{T}{T_B} \right) \right]$$

$$T_B \leq T < T_C \quad S_e(T) = \frac{a_g}{g} S \eta F_0$$

$$T_C \leq T < T_D \quad S_e(T) = \frac{a_g}{g} S \eta F_0 \left[\frac{T_C}{T} \right]$$

$$T_D \leq T \quad S_e(T) = \frac{a_g}{g} S \eta F_0 \left[\frac{T_C T_D}{T^2} \right]$$

$\eta = \sqrt{10/(5+\xi)} \geq 0.55$, where ξ is damping in percent

The S and spectra ordinate are based on the following equations:

$$S = S_s S_T$$

$$T_C = C_C T_C^{\,*};\ T_B = \frac{T_C}{3};\ T_D = 4\frac{a_g}{g} + 1.6$$

The parameter C_c, S_s and S_T are obtained using Soil Type and Topography.

Soil Type	S_s	C_c
A	1.00	1.00
B	$1.00 \leq 1.40 - 0.40 F_0 \frac{a_g}{g} \leq 1.20$	$1.10\left(T_c^*\right)^{-0.20}$
C	$1.00 \leq 1.70 - 0.6 F_0 \frac{a_g}{g} \leq 1.501$	$1.05\left(T_c^*\right)^{-0.33}$
D	$0.90 \leq 2.40 - 1.5 F_0 \frac{a_g}{g} \leq 1.80$	$1.25\left(T_c^*\right)^{-0.50}$
E	$1.00 \leq 2.00 - 1.10 F_0 \frac{a_g}{g} \leq 1.60$	$1.15\left(T_c^*\right)^{-0.40}$

Topography	S_T
T1	1.0
T2	$1.0 \leq 1 + 0.2\frac{h}{H} \leq 1.2$
T3	$1.0 \leq 1 + 0.2\frac{h}{H} \leq 1.2$
T4	$1.0 \leq 1 + 0.4\frac{h}{H} \leq 1.4$

2.26.24.2 Vertical Elastic Response Spectrum

$$0 \leq T < T_B \quad S_{ve}(T) = \frac{a_g}{g} S\eta F_v \left[\frac{T}{T_B} + \frac{1}{\eta F_0}\left(1 - \frac{T}{T_B}\right)\right]$$

$$T_B \leq T < T_C \quad S_{ve}(T) = \frac{a_g}{g} S\eta F_v$$

$$T_C \leq T < T_D \quad S_{ve}(T) = \frac{a_g}{g} S\eta F_v \left[\frac{T_C}{T}\right]$$

$$T_D \leq T \quad S_{ve}(T) = \frac{a_g}{g} S \eta F_v \left[\frac{T_C T_D}{T^2} \right]$$

$\eta = \sqrt{10/(5+\xi)} \geq 0.55$, where ξ is damping in percent

$S = S_s S_T$

$$F_v = 1.35 F_0 \left(\frac{a_g}{g} \right)^{0.5}$$

Soil Type	S_s	T_B	T_C	T_D
A, B, C, D, E	1.00	0.05 s	0.15 s	1.0 s

Topography	S_T
T1	1.0
T2	1.2
T3	1.2
T4	1.4

2.26.24.3 Design Horizontal Response Spectrum

The Design Horizontal Spectrum is same as Elastic Horizontal spectrum except the following:

The η parameter for Design spectrum is defined as $\eta = 1/q_h$

where, q_h is the structure behavior factor for horizontal component

2.26.24.4 Design Vertical Response Spectrum

The Design Vertical Spectrum is same as Elastic Vertical spectrum except the followings:

The η parameter for Design spectrum is defined as $\eta = 1/q_v$

where, q_v is the structure behavior factor for vertical component (1.5 for buildings, 1.0 for bridges).

2.26.25 2007 TSC Parameters for a Response Spectrum Function

The 2007 TSC response spectrum function is based on Figure 2.5 in Part II of the 2007 TSC. The digitization of these response spectra is based on Section 2.4.4.

The parameters required are a seismic zone factor, Z, local site classes for soil characteristics, R and importance factor, I. Any positive, nonzero value can be specified for the importance and R factor. The local site classes for soil characteristic can be input as Z1, Z2, Z3 or Z4; see Table 2.2 to 2.5 in the 2007 TSC for typical values.

2.26.26 1995 SI 413 Parameters for a Response Spectrum Function

The following parameters are input for the 1995 SI 413 response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = Ground Acceleration coefficient representing the effective peak acceleration as determined in 1995 SI 413 Section 202.1.

S = The Soil type of the site as determined by 1995 SI 413 Table 202.2.

I = The Importance factor as determined in 1995 SI 413.

K = The Seismic force reduction factor as determined from 1995 SI 413 Tables 5, 6 or 7.

2.26.27   KBC 2009 Parameters for a Response Spectrum Function

The following parameters are input for the 2009 KBC response spectrum function. Any positive, nonzero value can be input for these parameters.

S_1 = The design spectral response acceleration as specified in 2009 KBC Section 0306.3.1, Table 0306.3.1.

Ss = The design spectral response acceleration at a one second period. In KBC 2009, Ss is 2.5 times the value S_1 from Table 0306.3.1.

Site Class = Site class S_A to S_E as specified in KBC 2009 Section 0306.3.2.1, Table 0306.3.2.

The KBC 2009 response spectrum function is based on the procedure described in KBC 2009 Section 0306.3.

2.26.28   2013 Argentina Regulation 103 INPRES-CIRSOC Parameters for a Response Spectrum Function

The following parameters are input for the 2013 Spectrum of Argentina under Regulation 103 Inpres-CIRSOC response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The seismic zone as specified in 2013 Spectrum of Argentina under Regulation 103 Inpres-CIRSOC Annex A Section 2.2, Figure 2.

S = The soil type as specified in 2013 Spectrum of Argentina under Regulation 103 Inpres-CIRSOC Table 2.2.

$Group$ = The occupation category as specified in 2013 Spectrum of Argentina under Regulation 103 Inpres-CIRSOC Chapter 2.4.

R = The response modification factor as specified in 2013 Spectrum of Argentina under Regulation 103 Inpres-CIRSOC Table 5.1.

The 2013 Argentina Regulation 03 Inpres-CIRSOC response spectrum function is based on the procedure described in Inpres-CIRSOC Section 3.5.

2.26.29   1993 Chile Standard NCh433 + DS61 Parameters for a Response Spectrum Function

The following parameters are input for the 1993 Chile Standard NCh433 + DS61 response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The seismic zone as specified in 1993 Chile Standard NCh433 + DS61 Table 4.2.

S = The soil type as specified in 1993 Chile Standard NCh433 + DS61.

Category = The occupation category as specified in 1993 Chile Standard NCh433 + DS61 Table 4.1.

The 1993 Chile Standard NCh433 + DS61 response spectrum function is based on the procedure described in Section 6.3.5.

2.26.30   2003 Chile Standard 2369 Parameters for a Response Spectrum Function

The following parameters are input for the 2003 Chile Standard 2369 response spectrum function. Any positive, nonzero value can be input for these parameters.

I = The importance factor as specified in 2003 Chile Standard 2369 Section 4.3.2.

Z = The seismic zone as specified in 2003 Chile Standard 2369 Table 5.2.

S = The soil type as specified in 2003 Chile Standard 2369 Table 5.4.

R = The response modification factor as specified in 2003 Chile Standard 2369 Table 5.7.

The 2003 Chile Standard 2369 response spectrum function is based on the procedure described in Section 5.3.3.

2.26.31   2010 Colombian Regulations NSR–10 Parameters for a Response Spectrum Function

The following parameters are input for the 2010 Colombian Regulations NSR–10 response spectrum function. Any positive, nonzero value can be input for these parameters.

Aa = The effective peak acceleration as specified in 2010 Colombian Regulations NSR–10 Appendix A4.

Av = The effective peak velocity as specified in 2010 Colombian Regulations NSR–10 Appendix A4.

Ae = The reduced effective peak acceleration as specified in 2010 Colombian Regulations NSR–10 Appendix A4.

Ad = The effective peak acceleration for the damage threshold as specified in 2010 Colombian Regulations NSR–10 Appendix A4.

U = The Group of Use as specified in 2010 Colombian Regulations NSR–10 Section A.2.5.1.

Fa = The amplification factor of the acceleration for short periods as specified in 2010 Colombian Regulations NSR–10 A.2.4-3.

Fv = The amplification factor of the acceleration for interim periods as specified in 2010 Colombian Regulations NSR–10 A.2.4-3.

The 2010 Colombian Regulations NSR–10 response spectrum function is based on the procedure described in Section A2.6.1.

2.26.32   2011 Ecuador Standard NEC–11 Parameters for a Response Spectrum Function

The following parameters are input for the 2011 Ecuador Standard NEC–11 response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The Zone coefficient as specified in 2011 Ecuador Standard NEC–11 Table 2.2.

η = The η coefficient as specified in 2011 Ecuador Standard NEC–11.

TS = The Soil types as specified in 2011 Ecuador Standard NEC–11 Table 2.3.

Fa = The Site factor as specified in 2011 Ecuador Standard NEC–11 Table 2.5.

Fd = The Site factor as specified in 2011 Ecuador Standard NEC–11 Table 2.6.

Fs = The inelastic behavior factor of subsurface as specified in 2011 Ecuador Standard NEC–11 Table 2.7.

I = The Importance factor as specified in 2011 Ecuador Standard NEC–11 Table 2.9.

R = The Response Modification factor as specified in 2011 Ecuador Standard NEC–11 Table 2.14.

The 2011 Ecuador Standard NEC–11 response spectrum function is based on the procedure described in Section 2.5.5.1.

2.26.33   2010 Guatemala Standard AGIES NSE 2–10 Parameters for a Response Spectrum Function

The following parameters are input for the 2010 Guatemala Standard AGIES NSE 2–10 response spectrum function. Any positive, nonzero value can be input for these parameters.

I_0 = The Seismicity Index as specified in 2010 Guatemala Standard AGIES NSE 2–10 Annex A.

S_{cr} = The spectral sorted for short period as specified in 2010 Guatemala Standard AGIES NSE 2–10 Annex A.

S_{1r} = The spectral sorted for long period as specified in 2010 Guatemala Standard AGIES NSE 2–10 Annex A.

Fs = The Type of Seismic Source as specified in 2010 Guatemala Standard AGIES NSE 2–10 Table 4-5.

Dh = The Horizontal distance to seismic source as specified in 2010 Guatemala Standard AGIES NSE 2–10.

TS = The types of earthquake as specified in 2010 Guatemala Standard AGIES NSE 2–10.

F_a = The Site coefficient as specified in 2010 Guatemala Standard AGIES NSE 2–10 Table 4.2.

F_v = The Site coefficient as specified in 2010 Guatemala Standard AGIES NSE 2–10 Table 4.3.

R = The Response modification factor as specified in 2010 Guatemala Standard AGIES NSE 2–10 Table 2.14.

The 2010 Guatemala Standard AGIES NSE 2–10 response spectrum function is based on the procedure described in Section 4.3.4.2.

2.26.34   2004 Mexico Standard NTC–2004 Parameters for a Response Spectrum Function

The following parameters are input for the 2004 Mexico Standard NTC–2004 response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The Seismicity Zone as specified in Mexico Standard NTC–2004 Section 1.4.

G = The Ranking by Group as specified in Mexico Standard NTC–2004 chapter 7.

Q = The seismic behavior factor as specified in Mexico Standard NTC–2004 chapter 5.

I = The correction factor by irregularity as specified in Mexico Standard NTC–2004 chapter 6.

The Mexico Standard NTC–2004 response spectrum function is based on the procedure described in chapter 4.

2.26.35   2003 Peru Standard E.030 Parameters for a Response Spectrum Function

The following parameters are input for the 2003 Peru Standard E.030 response spectrum function. Any positive, nonzero value can be input for these parameters.

ZS =   The Seismic Zone as specified in 2003 Peru Standard E.030 Chapter 2, Figure 1.

CE =   The Occupation category as specified in 2003 Peru Standard E.030 Chapter 3, Table 3.

TS =   The Soil Types as specified in 2003 Peru Standard E.030 Chapter 2, Section 6.

SC =   The Structural Configuration as specified in 2003 Peru Standard E.030 Chapter 3, Section 11.

R =   The Response modification factor as specified in 2003 Peru Standard E.030 Chapter 3, Table 6.

The 2003 Peru Standard E.030 response spectrum function is based on the procedure described in Chapter 4, section 18.2b.

2.26.36   2011 Dominican Republic Standard R–001 Parameters for a Response Spectrum Function

The following parameters are input for the 2011 Dominican Republic Standard R–001 response spectrum function. Any positive, nonzero value can be input for these parameters.

LC =   The Location in near field as specified in 2011 Dominican Republic Standard R–001.

S_s = The sorted spectral reference for short period as specified in 2011 Dominican Republic Standard R–001.

S_1 = The sorted spectral reference for long period as specified in 2011 Dominican Republic Standard R–001.

F_a = The Soil factor associated to short period as specified in 2011 Dominican Republic Standard R–001.

F_v = The Soil factor associated to long period as specified in 2011 Dominican Republic Standard R–001.

Use = The Classification by user of structure as specified in 2011 Dominican Republic Standard R–001.

R_d = The Response modification factor as specified in 2011 Dominican Republic Standard R–001.

The 2011 Dominican Republic Standard R–001 response spectrum function is based on the procedure described in Chapter 3.

2.26.37   2001 Venezuela Standard COVENIN 1756–1 Parameters for a Response Spectrum Function

The following parameters are input for the 2001 Venezuela Standard COVENIN 1756–1 response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The Seismic Zone as specified in 2001 Venezuela Standard COVENIN 1756–1 Table 4.2.

S = The Spectral form as specified in 2001 Venezuela Standard COVENIN 1756–1 Table 5.1.

ρ = The Correction factor as specified in 2001 Venezuela Standard COVENIN 1756–1 Chapter 6.

U = The Site coefficient as specified in 2001 Venezuela Standard COVENIN 1756–1 Table 4.3.

R = The Response modification factor as specified in 2001 Venezuela Standard COVENIN 1756–1 Table 6.4.

The 2001 Venezuela Standard COVENIN 1756–1 response spectrum function is based on the procedure described in Chapter 7.

2.26.38   2015 Ecuador Standard NEC–SE–DS Parameters for a Response Spectrum Function

The following parameters are input for the 2015 Ecuador Standard NEC–SE–DS response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The Zone coefficient as specified in 2015 Ecuador Standard NEC–SE–DS Table 1.

Soil Type = The soil type as specified in 2015 Ecuador Standard NEC–SE–DS Table 2.

η = The η coefficient as specified in 2015 Ecuador Standard NEC–SE–DS Section 3.3.1.

Fa = The Site factor as specified in 2015 Ecuador Standard NEC–SE–DS Table 3.

Fd = The Site factor as specified in 2015 Ecuador Standard NEC–SE–DS Table 4.

Fs = The inelastic behavior factor of subsurface as specified in 2015 Ecuador Standard NEC–SE–DS Table 5.

I = The Importance factor as specified in 2015 Ecuador Standard NEC–SE–DS Table 6.

R = The Response Modification factor as specified in 2015 Ecuador Standard NEC–SE–DS Table 15 and 16.

The 2015 Ecuador Standard NEC–SE–DS response spectrum function is based on the procedure described in Section 3.3.1.

2.26.39   2014 Peru Standard E.030 Parameters for a Response Spectrum Function

The following parameters are input for the 2014 Peru Standard E.030 response spectrum function. Any positive, nonzero value can be input for these parameters.

ZS =   The Seismic Zone as specified in 2014 Peru Standard E.030 Chapter 2, Figure 1, Table 1.

CE =   The Occupation category as specified in 2014 Peru Standard E.030 Chapter 3, Table 5.

SoilType = The soil type as specified in 2014 Peru Standard E.030 Chapter 2, section 2.3.1.

Ia =   The irregularity factor as specified in 2014 Peru Standard E.030 Chapter 3, Section 3.6, Table 8.

Ip =   The irregularity factor as specified in 2014 Peru Standard E.030 Chapter 3, Section 3.6, Table 9.

$R0$ =   The Response modification factor as specified in 2014 Peru Standard E.030 Chapter 3, Table 7.

The 2014 Peru Standard E.030 response spectrum function is based on the procedure described in Chapter 2, section 2.5.

2.26.40   2008 Mexico CFE Parameters for a Response Spectrum Function

The following parameters are input for the 2008 Mexico Standard CFE response spectrum function. Any positive, nonzero value can be input for these parameters.

Z =   The Seismic Zone as specified in Mexico CFE 2008 code. The seismic zone are A, B, C or D.

G =   The Structural Classification as specified in Mexico CFE 2008 There are two types of structural classification i.e., 1 and 2.

S = The Soil Type as specified in Mexico CFE 2008. Soil type can be either I, II or III.

Q = The seismic behavior factor as specified in Mexico CFE 2008. The values are 1, 1.5, 2, 3 and 4 .

I = The correction factor by irregularity as specified in Mexico CFE 2008. Correction factor can be either 0.8 or 1.0.

2.26.41   1993 Mexico CFE Parameters for a Response Spectrum Function

The following parameters are input for the 1993 Mexico Standard CFE response spectrum function. Any positive, nonzero value can be input for these parameters.

Z = The Seismic Zone as specified in Mexico CFE 1993 code. The seismic zone are A, B, C or D.

G = The Structural Classification as specified in Mexico CFE 1993 There are two types of structural classification i.e., 1 and 2.

S = The Soil Type as specified in Mexico CFE 1993. Soil type can be either I, II or III.

Q = The seismic behavior factor as specified in Mexico CFE 1993. The values are 1, 1.5, 2, 3 and 4 .

I = The correction factor by irregularity as specified in Mexico CFE 1993. Correction factor can be either 0.8 or 1.0.

2.26.42   2010 Costa Rica Parameters for a Response Spectrum Function

The following parameters are input for the 2010 Costa Rica Seismic Design code response spectrum function. Any positive, nonzero value can be selected for these parameters.

Zone = The Seismic Zone as specified in Costa Rica 2010 seismic code. The seismic zone are II, III or IV.

Soil = The Soil Type as specified in Costa Rica 2010 seismic code. Soil type can be either S1, S2, S3 or S4.

Occupancy = There are 4 occupancy Groups i.e., A to D in Costa Rica 2010 seismic code.

Overstrength = The ductility overstrength factor can be 1, 1.5, 2, 3, 4 and 6 as specified in Costa Rica 2010 seismic code.

2.26.43   SP 14.13330.2014 Response Spectrum Function

The Russian SP 14.13330.2014 response spectrum function is constructed based on input parameters for the spectrum direction, region seismicity at the construction site, soil category, nonlinear soil deformation factor, and three additional factors.

The spectrum direction can be horizontal or vertical, for either buildings or bridges. The region seismicity can be 6, 7, 8, or 9. The soil category can be I, II, III, or IV.

The factor K_0 is only applicable for buildings and should be input with a value greater than zero and less than or equal to two.

The factor K_1 should be greater than zero and less than or equal to one. The factor K_ψ is only applicable for horizontal spectra and should be greater than or equal to 0.5 and less than or equal to 1.5.

Nonlinear soil deformation can be taken into account for buildings with a soil category of III or IV by inputting a value for a_{soil} that is greater than zero and less than or equal to one.

The following combinations of the region seismicity and soil category are no permitted by the code:

- Soil Category – I and Seismicity = 6 or 7

- Soil Category – II and Seismicity = 6

- Soil Category = III or IV and Seismicity = 9

The spectral acceleration, S_a, is calculated as follows:

Buildings – $S_a = a_{soil} \cdot a_{direct} \cdot K_0 \cdot K_1 \cdot A \cdot K_\Psi \cdot \beta_i$

Bridges – $S_a = a_{direct} \cdot K_1 \cdot A \cdot K_\Psi \cdot \beta_i$

where,

$a_{direct} = 0.75$ for vertical response spectra

$a_{direct} = 1.0$ for horizontal response spectra

The acceleration value, A, depends on the earthquake intensity and the soil type, as shown in the following table.

	I	II	III or IV
6	N/A	N/A	1 m/s²
7	N/A	1 m/s²	2 m/s²
8	1 m/s²	2 m/s²	4 m/s²
9	2m/s²	4 m/s²	N/A

The value β_i is calculated based on the period of interest and shall be greater than or equal to 0.8. The equations used depend on the soil type. For soil types I and II, β_i is calculated as:

$$\beta_i = 1 + 15 \cdot T_i \quad for \quad T_i \leq 0.1sec$$
$$\beta_i = 2.5 \quad for \quad 0.1sec < T_i < 0.4sec$$
$$\beta_i = 2.5\left(0.4/T_i\right)^{0.5} \quad for \quad T_i \geq 0.4sec$$

For soil types III and IV, β_i is calculated as:

$$\beta_i = 1 + 15 \cdot T_i \quad for \quad T_i \leq 0.1sec$$
$$\beta_i = 2.5 \quad for \quad 0.1sec < T_i < 0.8sec$$
$$\beta_i = 2.5\left(0.8/T_i\right)^{0.5} \quad for \quad T_i \geq 0.8sec$$

Chapter 3
Automatic Wind Loads

This chapter documents the automatic wind lateral static load patterns that can be generated. Automatic wind loads can be generated in any arbitrary horizontal direction for the following codes:

- 1994 UBC
- 1997 UBC
- 1996 BOCA
- BS 6399-95
- 1995 NBCC
- 2005 NBCC
- 2010 NBCC
- 2015 NBCC
- ASCE 7-88
- ASCE 7-95
- ASCE 7-02
- 2006 IBC/ASCE 7-05

- ASCE 7-10
- 1987 RCDF (Mexico)
- 2010 Chinese
- API 4F 2008
- 2005 Eurocode 1, Part 1-4
- 2011 AS/NZS 1170.2
- 2002 AS/NZS 1170.2
- 1987 Indian IS:875
- 2008 Italian NTC
- 1997 Turkish 498

3.1   Defining Automatic Wind Load Patterns

The commands used to define automatic seismic static load patterns are as specified in the on-line, program-specific Help.

Each automatic static lateral load must be in a separate load pattern. That is, two or more automatic static lateral loads cannot be specified in the same load pattern. However, additional user-defined loads can be added to a load pattern that includes an automatic static lateral load. A separate automatic static load pattern must be defined for each direction of wind load.

Note that the actual forces associated with an automatic static lateral load are not calculated until an analysis has been run. Thus, the resultant automatic lateral loads cannot be reviewed until after an analysis has been run.

3.2   Automatic Wind Load Patterns

The forms defining the automatic wind loads consist of four data sets; some of the data sets are dependent on the exposure selected.

One data set defines the exposure by selecting loading based on diaphragms or area objects. Another data set defines the wind exposure parameters, and a third set defines the exposure height. The fourth set is for specifying the wind coefficients. The data in the first three sets is common to all of the codes and is described in the subsections that follow. The wind coefficient data set is code-dependent and is described separately for each code later in this chapter.

Wind loads also can be user defined, which is described at the end of this chapter.

When the code is ASCE 7-95, ASCE 7-02, ASCE 7-05, ASCE 7-10 or NBCC 2015, automatic wind load patterns may become multi-stepped. For example, a wind load may be specified as occurring at multiple angles around the structure. These will be treated as a single load pattern and will be analyzed in a single load case, producing multiple output steps of response, one for each separate step of the load.

When a multi-stepped load pattern is applied in a load case, the following rules govern how it will be handled:

1. In a linear static load case, the load case will internally be run as a multi-linear static load case, producing multiple output steps.

2. In a nonlinear static load case, the load case will internally be run as a new type of staged-construction load case, where each stage starts from the beginning of the load case, producing results similar to the multi-linear static load case.

3. All other load cases (including staged-construction) are unchanged, and will treat the load pattern as single-stepped, using the first step of the multi-stepped load pattern.

4. For cases 1 and 2, if several multi-stepped load patterns are applied in a single load case, they superpose on a step-wise basis. For example, if load pattern A has 3 steps and load pattern B has 5 steps, the load case will apply five independent load steps: A1+B1, A2+B2, A3+B3, B4, B5. If a non-stepped load pattern is applied, such as Dead, it is applied in every load step.

3.2.1 Exposure

The automatically calculated wind loads may be determined by exposure to diaphragms or to area objects (i.e., exterior cladding, walls, and roofs).

If exposure from the extents of diaphragms is selected, a separate lateral load is created for each diaphragm present at a story level. The wind loads calculated at any story level are based on the story level elevation, the story height above and below that level, the assumed exposure width for the diaphragm(s) at the story level, and various code-dependent wind coefficients.

If area objects are used to model the actual in-plane stiffness of the diaphragm and automatic wind loads are to be created using the diaphragm option, one or more dummy diaphragms must be defined at each story level. Assign a dummy diaphragm to just one point object at a story level; that point object becomes the location where the wind load is applied. However, a diaphragm consisting of a single point object will have a zero exposure width, so input a user-defined

exposure width for the dummy diaphragm to generate a non-zero wind load (use the **Modify/Show Exposure Widths** button on the Wind Loading form).

If exposure from area objects is selected, wind loads will be generated on each area object that has been assigned a wind pressure coefficient, C_p. The wind load pattern must be defined before assigning the C_p values to the area objects. The wind loads calculated at an area object are based on the elevation of the object, the dimensions of the object, and various code-dependent wind coefficients.

Unlike the diaphragm exposure option that generates only lateral wind loads, the exposure from area objects option will generate wind loads normal to any area object, regardless of its orientation. Thus, this option may be used to generate vertical as well as lateral loads.

3.2.2   Wind Exposure Parameters

The wind exposure parameters are available only when calculating lateral wind loads using the exposure from extents of diaphragms option. These input values are not available when using the exposure from area objects method because the wind coefficients are assigned directly to the area objects using a loads command.

When specifying the wind direction, indicate the direction of the wind by an angle measured in degrees. An angle of 0 degrees means the wind is blowing in the positive global *X*-direction; that is, it is blowing from the negative global *X*-direction to the positive global *X*-direction. An angle of 90 degrees means the wind is blowing in the positive global *Y*-direction. An angle of 180 degrees means the wind is blowing in the negative global *X*-direction. An angle of 270 degrees means the wind is blowing in the negative global *Y*-direction.

Any angle for the wind direction can be input. The angle is always measured counterclockwise from the positive global *X*-axis. A positive angle appears counterclockwise as you look down on the model in the negative global *Z*-direction.

The windward coefficient, *Cp*, and the leeward coefficient, *Cp*, are used in calculating the wind pressures on the windward and leeward sides of the diaphragms, respectively. The windward side of a diaphragm is the side exposed to the wind, while the opposite side is the leeward side.

Click the **Modify/Show Exposure Widths** button to review and modify the exposure widths calculated by the programs for each diaphragm. By default, the wind exposure width for a diaphragm is equal to the calculated width of the diaphragm in a direction perpendicular to the direction of the wind load.

The maximum width of the diaphragm perpendicular to the direction of the wind loading is calculated using the following three-step process.

- Transform the coordinates of all of the point objects that are part of the diaphragm constraint into a system of coordinates that is parallel and perpendicular to the specified direction of wind loading.

- Find the point objects that have the maximum and minimum coordinates perpendicular to the direction of the wind load. For example, if the wind load is in the global *X*-direction, find the point objects with the maximum and minimum global *Y*-coordinates.

- Subtract the minimum perpendicular coordinate from the maximum perpendicular coordinate to obtain the diaphragm width perpendicular to the wind load.

By default, the point where the wind load is applied to a diaphragm is the calculated geometric center of the diaphragm. Modify the assumed wind load application point and the default exposure width on the Wind Exposure Width Data form, which displays when the **Modify/Show Exposure Widths** button is clicked.

NOTE: It is recommended to only use "**Area Exposure Method**" for specifying Auto Wind Load when Multiple Towers are present in a single model.

3.2.3   Wind Exposure Height

The top story/maximum elevation and a bottom story/minimum elevation input values specify the elevation range over which the structure is exposed to wind.

The top story/maximum global Z indicates the highest story level to be assumed exposed to wind loading for the purposes of calculating the automatic wind load. In most instances the top story should be the uppermost story level/elevation in the building and this is the default value.

In some instances, for example where penthouses are included in the model, it may be more convenient to indicate that the top story level for automatic wind loading is the main roof level. User-defined loads can then be added to the load pattern to account for the wind loads acting on the penthouse.

The bottom story/minimum global Z indicates the lowest story level that is exposed to wind loading. It is assumed that all stories above the bottom story are loaded by the wind.

By default the bottom story is assumed to be the base level of the structure. In some cases, it may be advantageous to specify a higher level as the bottom story for wind loading. One example of this might be if a building has several below-grade levels that should not receive any wind loading.

Figure 3-1 gives a representation of how loads are distributed to the diaphragms when using the exposure from extents of diaphragms method.
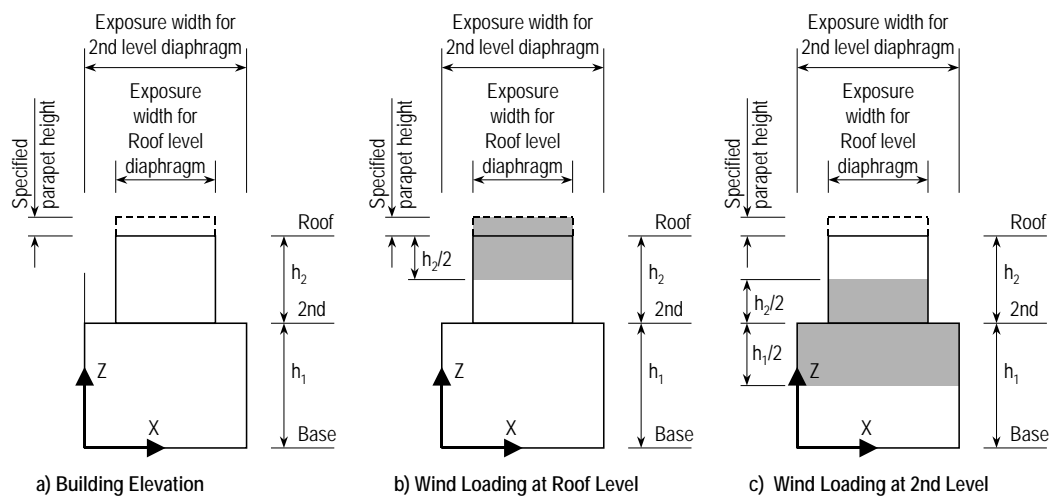
Figure 3-1: Example extent of wind loading

Figure 3-1a shows an elevation of a two-story building with diaphragms at each story level. Assume the wind load is to be automatically calculated for the *Y*-direction. Thus, the wind load is acting on the face of the building shown in Figure 3-1a.

The shaded area in Figure 3-1b illustrates the extent of the wind load that is applied to the roof level diaphragm. The shaded area in Figure 3-1c illustrates the extent of the wind load that is applied to the 2nd level diaphragm.

When using the exposure from area objects method, the exposure heights allows the programs to determine how much of each area object is exposed to wind.

3.3   1994 UBC Wind Loads

3.3.1   Input Wind Coefficients

Three wind coefficients are input for 1994 UBC wind loads. They are the basic wind speed in miles per hour (mph), the exposure type, and the wind importance factor, I_w.

The basic wind speed is described in 1994 UBC Sections 1614 and 1616. A typical range of values for the basic wind speed is 70 to 130 mph.

The exposure types are described in 1994 UBC Sections 1614 and 1617. The exposure type can be B, C or D. No other values are allowed. The wind importance factor can be found in 1994 UBC Table 16-K. The wind importance factor, I_w, should be input, not one of the seismic importance factors, I or I_p. A typical range of values for I_w is 1.00 to 1.15.

3.3.2   Algorithm for 1994 UBC Wind Loads

ETABS automatic wind loads for the 1994 UBC are based on Sections 1614 through 1619 of the 1994 UBC.

The wind loads applied in ETABS are a modified version of the Method 2 (Projected Area Method) as described in Section 1619.3 of the 1994 UBC. ETABS applies horizontal wind loads on the vertical projected area as described in Section 1619.3. ETABS has two modifications to the requirements of Section 1619.3. The first modification is that ETABS does not automatically apply vertical wind loads over the projected horizontal area. To include these vertical wind loads in the load case, the user must manually include them.

The other modification is that ETABS applies the method to structures of any height. It does not limit it to structures less than 200 feet high as discussed in 1994 UBC Section 1619.3.

The shape of the horizontal projected area is determined based on the story heights and the input exposure widths for each rigid diaphragm. ETABS uses 1994 UBC Equation 18-1 to determine the wind pressure, P, at any point on the surface of the horizontal projected area.

$$P = C_e \, C_q \, q_s \, I_w \qquad \qquad \text{(UBC 94 Eqn. 18-1)}$$

where,

C_e = Combined height, exposure and gust factor coefficient, as given in 1994 UBC Table 16-G.

C_q = Pressure coefficient for the structure, as given in 1994 UBC Table 16-H.

q_s = Wind stagnation pressure at the standard height of 33 feet, as given in 1994 UBC Table 16-F.

I_w = Importance factor, as input by the user.

ETABS determines the C_e coefficient from 1994 UBC Table 16-G using the input exposure type and the input bottom story. For use in 1994 UBC Table 16-G the elevation of the input bottom story is assumed to be zero (0). ETABS uses linear interpolation to determine the value of the C_e coefficient at heights above 15 feet that are not listed in 1994 UBC Table 16-G.

ETABS determines the C_q coefficient from 1994 UBC Table 16-H. ETABS uses the values for Primary Frames and Systems using Method 2 (the projected area method). Thus for buildings 40 feet or less in height, ETABS uses $C_q = 1.3$, and for buildings more than 40 feet in height, ETABS uses $C_q = 1.4$.

ETABS determines q_s from 1994 UBC Table 16-F.

$$q_s = 0.00256 \, V^2 \geq 10 \text{ psf}$$

where,

q_s = Wind stagnation pressure at the standard height of 33 feet, psf.

V = Basic wind speed as input by the user, mph.

Note the units that are specified for q_s and V.

ETABS distributes the pressures, P, on the surface of the horizontal projected area to each rigid diaphragm on a tributary area basis as shown in Figure 3-1.

3.4   1997 UBC Wind Loads

3.4.1   Input Wind Coefficients

Three wind coefficients are input for 1997 UBC wind loads. They are the basic wind speed in miles per hour (mph), the exposure type, and the wind importance factor, I_w.

The basic wind speed is described in 1997 UBC Sections 1616 and 1618. A typical range of values for the basic wind speed is 70 to 130 mph.

The exposure types are described in 1997 UBC Sections 1616 and 1619. The exposure type can be B, C, or D. No other values are allowed.

The wind importance factor can be found in 1997 UBC Table 16-K. The wind importance factor, I_w—not one of the seismic importance factors, I or I_p—should be input. A typical range of values for I_w is 1.00 to 1.15.

3.4.2   Algorithm for 1997 UBC Wind Loads

3.4.2.1   Exposure from Extents of Diaphragms

Automatic wind loads for the 1997 UBC are based on Sections 1616 through 1621 of the 1997 UBC.

The wind loads applied when using the exposure from extents of diaphragms method are based on a modified version of Method 2 (Projected Area Method) as described in Section 1621.3 of the 1997 UBC. Horizontal wind loads are applied on the vertical projected area as described in Section 1621.3. The programs have two modifications to the requirements of Section 1621.3. The first modification is that the programs do not automatically apply vertical wind loads over the projected horizontal area. To include those vertical wind loads in the same load pattern, the user must manually include them. The other modifi-

cation is that the programs apply the method to structures of any height. The modification does not limit structures to less than 200 feet high, as discussed in 1997 UBC Section 1621.3.

The shape of the vertical projected area is determined based on the story heights and the input exposure widths for each diaphragm. (UBC Eqn. 20-1) is used to determine the wind pressure, P, at any point on the surface of the vertical projected area.

$$P = q_s\, I_w\, (C_{q\text{-windward}}\, C_{e\text{-windward}} + C_{q\text{-leeward}}\, C_{e\text{-leeward}}) \qquad \text{(UBC Eqn. 20-1)}$$

where,

q_s = Wind stagnation pressure at the standard height of 33 feet, as given in 1997 UBC Table 16-F.

I_w = Importance factor as input by the user.

$C_{q\text{-windward}}$ = Windward pressure coefficient as input by the user.

$C_{e\text{-windward}}$ = Windward combined height, exposure and gust factor coefficient at the height of interest, as given in 1997 UBC Table 16-G.

$C_{q\text{-leeward}}$ = Leeward pressure coefficient as input by the user.

$C_{e\text{-leeward}}$ = Leeward combined height, exposure, and gust factor coefficient, evaluated at the specified top story level, as given in 1997 UBC Table 16-G.

The C_e coefficient is determined from 1997 UBC Table 16-G using the input exposure type and the elevation from the input bottom story. Linear interpolation is used to determine the value of the C_e coefficient at heights above 15 feet that are not listed in 1997 UBC Table 16-G.

q_s is determined from the following equation:

$$q_s = 0.00256\, V^2 \geq 10 \text{ psf} \qquad\qquad \text{(UBC Table 16-F)}$$

where,

q_s = Wind stagnation pressure at the standard height of 33 feet, psf.

V = Basic wind speed as input by the user, mph.

Note the units that are specified for q_s and V. Also note that the preceding equation is consistent with 1997 UBC Table 16-F.

The programs distribute the pressures, *P*, on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1.

3.4.2.2   Exposure from Area Objects

Automatic wind loads for the 1997 UBC are based on Sections 1616 through 1621 of the 1997 UBC.

The wind loads applied when using the exposure from area objects method are based on Method 1 (Normal Force Method) as described in Section 1621.2 of the 1997 UBC. Wind loads are applied on the vertical and horizontal surfaces of the user selected area objects as described in Section 1621.2.

(UBC Eqn. 20-1) is used to determine the wind pressure, *P*, at any point on the surface of the area objects.

$$P = C_e\, C_p\, q_s\, I_w \qquad\qquad \text{(UBC Eqn. 20-1)}$$

where,

C_e = Combined height, exposure, and gust factor coefficient as given in 1997 UBC Table 16-G. This value is evaluated at the height of interest for windward exposures, and at the top story level for leeward objects.

C_p = Windward or leeward pressure coefficient assigned to the area object by the user.

q_s = Wind stagnation pressure at the standard height of 33 feet as given in 1997 UBC Table 16-F.

I_w = Importance factor as input by the user.

The value for q_s is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The programs distribute the pressures, *P*, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.5   1996 BOCA Wind Loads

3.5.1   Input Wind Coefficients

Four wind coefficients are input for 1996 BOCA wind loads. They are the basic wind speed in miles per hour (mph), the exposure category, and the wind importance factor, I, and the gust response factor, G_h.

The basic wind speed is described in 1996 BOCA Section 1609.3. A typical range of values for the basic wind speed is 70 to 130 mph.

The exposure categories are described in 1996 BOCA Section 1609.4. The exposure category can be A, B, C or D. No other values are allowed.

The wind importance factor, I, is described in 1996 BOCA Section 1609.5. A typical range of values for I is 0.90 to 1.23.

The gust response factor, G_h, is discussed in 1996 BOCA Section 1609.7 and in Table 1609.7(5). Specify that the gust response factor is (a) calculated based on the height (distance) of the specified top story above the specified bottom story and the exposure category in accordance with the code using Table 1609.7(5) or (b) a value input by the user. Note that in 1996 BOCA Section 1609.7, the following statement is made about G_h.

> The gust response factor for buildings which have a height to least horizontal dimension ratio greater than 5 or a fundamental frequency less than one cycle per second (period greater than 1 second) shall be calculated by an approved rational analysis that incorporates the dynamic properties of the main wind force-resisting system.

When the Per Code option for the gust response factor is selected, the programs do *not* check the height-to-least-horizontal-dimension ratio or the building period and it does *not* determine the gust factor using an approved rational analysis incorporating the dynamic properties of the main wind force-resisting system. It is assumed that the user will do this, if necessary, and provide a user defined value for G_h. A typical range of values for G_h is 1.00 to 2.36.

3.5.2   Algorithm for 1996 BOCA Wind Loads

3.5.2.1   Exposure from Extents of Diaphragms

Automatic wind loads for the 1996 BOCA are based on Section 1609 of the 1996 BOCA.

The wind loads applied are a modified version of those described in 1996 BOCA Section 1609.7. Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must manually include them.

The following equation is used to determine the wind pressure, P, at any point on the surface of the vertical projected area.

$$P = P_v \, I \, [K_z \, G_h \, C_{p\text{-windward}} + K_h \, G_h \, C_{p\text{-leeward}}] \qquad \text{(Table 1609.7)}$$

where,

P_v = Basic velocity pressure given in 1996 BOCA Table 1609.7(3).

I = Importance factor as input by the user.

K_z = Velocity pressure exposure coefficient at the height of interest as given in 1996 BOCA Table 1609.7(4).

G_h = Gust response factor as given in 1996 BOCA Table 1609.7(5) or as user specified.

$C_{p\text{-windward}}$ = Windward pressure coefficient as input by the user.

K_h = Velocity pressure exposure coefficient, evaluated at the specified top story level, as given in 1996 BOCA Table 1609.7(4).

$C_{p\text{-leeward}}$ = Leeward pressure coefficient as input by the user.

The P_v coefficient is determined from the following equation.

$$P_v = 0.00256 \, V^2 \geq 10 \text{ psf} \qquad \text{(Table 1609.7(3))}$$

where,

P_v = Basic velocity pressure, psf.

V = Basic wind speed as input by the user, mph.

Note the units specified for P_v and V.

The K_z coefficient is determined from 1996 BOCA Table 1609.7(4) using the input exposure category and the input bottom story. For use in 1996 BOCA Table 1609.7(4), the input bottom story/minimum elevation is assumed to be ground level. The programs use linear interpolation to determine the value of the K_z coefficient at heights above 15 feet that are not listed in 1996 BOCA Table 1609.7(4).

For discussion of the gust response factor, G_h, refer to the previous section entitled "Input Wind Coefficients for 1996 BOCA."

The K_h coefficient is determined from 1996 BOCA Table 1609.7(4) using the input exposure category and the height of the input top story above the input bottom story. Linear interpolation is used to determine the value of the K_h coefficient at heights above 15 feet that are not listed in 1996 BOCA Table 1609.7(4).

The programs distribute the pressures, P, on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1.

3.5.2.2 Exposure from Area Objects

Automatic wind loads for the 1996 BOCA are based on Section 1609 of the 1996 BOCA.

The wind loads applied when using the exposure from area objects method are as described in 1996 BOCA Section 1609.7. Wind loads are applied on the vertical and horizontal surfaces of the user selected area objects as described in Section 1609.7.

The following equations are used to determine either the windward or leeward wind pressure, P, at any point on the surface of the area objects.

$$P_{\text{windward}} = P_v \, I \, K_z \, G_h \, C_{p\text{-windward}} \qquad \text{(Table 1609.7)}$$

or

$$P_{\text{leeward}} = P_v \, I \, K_h \, G_h \, C_{p\text{-leeward}} \qquad \text{(Table 1609.7)}$$

where,

P_v = Basic velocity pressure given in 1996 BOCA Table 1609.7(3).

I = Importance factor as input by the user.

K_z = Velocity pressure exposure coefficient at the height of interest as given in 1996 BOCA Table 1609.7(4).

G_h = Gust response factor as given in 1996 BOCA Table 1609.7(5) or as user specified.

$C_{p\text{-windward}}$ = Windward pressure coefficient as assigned to the area object by the user.

K_h = Velocity pressure exposure coefficient, evaluated at the specified top story level, as given in 1996 BOCA Table 1609.7(4).

$C_{p\text{-leeward}}$ = Leeward pressure coefficient as assigned to the area object by the user.

The values for P_v, K_z, and K_h are the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The programs distribute the pressures, P, on the surface of each area object, which in turn creates loads on the joints connected to the area objects

3.6   1995 BS 6399 Wind Loads

3.6.1   Input Wind Coefficients

Three wind coefficients are input for 1995 BS 6399 wind loads. They are the effective wind speed in meters per second (m/s), the size effect factor, and the dynamic augmentation factor.

The effective wind speed, V_e, is described in 1995 BS 6399 Section 2.2.3.

The size effect factor for external pressures, C_a, is described in 1995 BS 6399 Section 2.1.3.4. A typical range of values for C_a is 0.52 to 1.00.

The dynamic augmentation factor, C_r, is described in 1995 BS 6399 Section 1.6.1. A typical range of values for C_r is 0 to 0.25.

Note that in 1995 BS 6399 Section 1.6.2 the following statement is made about C_r:

> This part of BS 6399 does not apply when the value of dynamic augmentation factor exceeds the limits shown in figure 3. Buildings falling outside these limits should be assessed using established dynamic methods.

This typically means that when $C_r \geq 0.25$, the structure is assumed to be dynamic and the methodology for establishing wind loads described herein is not applicable. However, the program allows the user to input any value, and performs no check to ensure that C_r is less than 0.25.

3.6.2   Algorithm for 1995 BS 6399 Wind Loads

3.6.2.1   Exposure from Extents of Diaphragms

Automatic wind loads for the 1995 BS 6399 are based on 1995 BS 6399 Section 2.

The wind loads applied when using the exposure from extents of diaphragms method are based on a modified version of the Standard method as described in Section 2.1 of the 1995 BS 6399. Horizontal wind loads are applied on the vertical projected area as described in Section 2. The programs have two modifications to the requirements of Section 2. The first modification is that the programs do not apply vertical wind loads automatically over the projected horizontal area. To include those vertical wind loads in the same load pattern, the user must include them manually. The other modification is that the programs apply the method to structures of any height. The modification does not limit structures to less than 100 meters high, as discussed in 1995 BS Section 1.8.1.

The shape of the vertical projected area is determined based on the story heights and the input exposure widths for each diaphragm. Eqn. 2.3.1.6(7) is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = 0.85 \ q_s \ C_a \ (C_{p\text{-front}} + C_{p\text{-rear}}) \ (1 + C_r) \qquad \text{(Eqn. 2.3.1.6(7))}$$

where,

q_s =   Dynamic pressure as given in 1995 BS 6399 Table 2.

C_a =   Size effect factor as input by the user.

$C_{p\text{-front}}$ =   External pressure coefficient on the windward side as input by the user.

$C_{p\text{-rear}}$ =   External pressure coefficient on the leeward side as input by the user.

C_r =   Dynamic augmentation factor as input by the user.

Note that the factor 0.85 accounts for the non-simultaneous action between the front and rear faces.

q_s is determined from (Eqn. 2.2.2.1(1)).

$$q_s = 0.613 \ V_e^2 \qquad \text{(Eqn. 2.2.2.1(1))}$$

where,

q_s =   Dynamic pressure, *Pa*.

V_e =   Effective wind speed as input by the user, m/s.

Note the units that are specified for q_s and V_e. Also note that (Eqn. 2.2.2.1(1)) is consistent with 1995 BS 6399 Table 2.

The programs distribute the pressures, *p*, on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1.

3.6.2.2 Exposure from Area Objects

Automatic wind loads for 1995 BS 6399 are based on Section 2.

The wind loads applied when using the exposure from area objects method are based on a modified version of the Standard method as described in Section 2.1 of 1995 BS 6399. Wind loads are applied on the vertical and horizontal surfaces of the user selected area objects as described in Section 2.

Eqn. (2.1.3.6(7)) is used to determine the wind pressure, p, at any point on the surface of the area objects.

$$p = 0.85 \, q_s \, C_p \, C_a \, (1 + C_r) \qquad \text{(Eqn. 2.1.3.6(7))}$$

where,

q_s = Dynamic pressure as given in 1995 BS 6399 Table 2.

C_p = Windward (front) or leeward (rear) external pressure coefficient assigned to the area object by the user.

C_a = Size effect factor as input by the user.

C_r = Dynamic augmentation factor as input by the user.

Note that the factor 0.85 accounts for the non-simultaneous action between the front and rear faces.

The value for q_s is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.7   1995 NBCC Wind Loads

3.7.1   Input Wind Coefficients

Two wind coefficients are input for 1995 NBCC wind loads. They are the velocity pressure, q, in kPa and the gust effect factor, C_g.

The velocity pressure, q, can be obtained from 1995 NBCC Appendix C. A typical range of values for the velocity pressure is 0.20 to 0.90 kPa. Any positive value or zero is allowed.

The gust effect factor, C_g, is discussed in 1995 NBCC Sentence 4.1.8.1(6). The default value is 2.0. Any positive value is allowed.

3.7.2 Algorithm for 1995 NBCC Wind Loads

3.7.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for 1995 NBCC are based on Section 4.1.8.1 of the 1995 NBCC.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the load pattern, the user must include them manually.

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = q \, C_g \, [C_{p\text{-winward}} \, C_{e\text{-windward}} + C_{p\text{-leeward}} \, C_{e\text{-leeward}}] \qquad \text{(1995 NBCC Eqn. 4.1.8.1(1))}$$

where,

- q = Velocity pressure as input by the user.

- C_g = Gust effect factor as input by the user.

- $C_{p\text{-windward}}$ = External pressure coefficient for the windward wall as input by the user.

- $C_{e\text{-windward}}$ = Exposure factor for the windward wall.

- $C_{p\text{-leeward}}$ = External pressure coefficient for the leeward wall as input by the user.

- $C_{e\text{-leeward}}$ = Exposure factor for the leeward wall.

$C_{e\text{-windward}}$ is determined from (Eqn. 4.1.8.1(5)).

$$C_{e-\text{windward}} = \left(\frac{h}{10}\right)^{1/5} \geq 0.9 \qquad \text{(1995 NBCC Eqn. 4.1.8.1(5))}$$

where,

- h = Distance from the input bottom story/minimum level to the elevation considered, meters.

$C_{e\text{-leeward}}$ is determined from (1995 NBCC Eqn. 4.1.8.1(5)).

$$C_{e-\text{leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{1/5} \geq 0.9 \qquad \text{(1995 NBCC Eqn. 4.1.8.1(5))}$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis, as shown in Figure 3-1.

3.7.2.2 Exposure from Area Objects

Automatic wind loads for 1995 NBCC are based on Section 4.1.8.1 of the 1995 NBCC.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in 1995 NBCC Section 4.1.8.1.

The following equations is used to determine the wind pressure, p, at any point on the surface of the area objects.

$$p = q\, C_e\, C_g\, C_p \qquad \text{(1995 NBCC Eqn. 4.1.8.1(1))}$$

where,

q = Velocity pressure as input by the user.

C_e = Exposure factor.

C_g = Gust effect factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

C_e for a windward facing area object is determined from (1995 NBCC Eqn. Eqn. 4.1.8.1(5)).

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{1/5} \geq 0.9 \qquad\qquad (1995 \text{ NBCC Eqn. } 4.1.8.1(5))$$

where,

h = Distance from the input bottom story/minimum level to the elevation considered, meters.

C_e for a leeward facing area object is determined from (1995 NBCC Eqn. 4.1.8.1(5)).

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{1/5} \geq 0.9 \qquad\qquad (1995 \text{ NBCC Eqn. } 4.1.8.1(5))$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.8   2005 NBCC Wind Loads

3.8.1   Input Wind Coefficients

Three wind coefficients are input for 2005 NBCC wind loads. They are the velocity pressure, q, in kPa, the gust effect factor, C_g, and the importance factor, I.

The velocity pressure, q, can be obtained from 2005 NBCC Appendix C. A typical range of values for the velocity pressure is 0.27 to 1.23 kPa. Any positive value or zero is allowed.

The gust effect factor, C_g, is discussed in 2005 NBCC Sentence 4.1.7.1(6). The default value is 2.0. Any positive value is allowed.

The importance factor, I, is described in 2005 NBCC Table 4.1.7.1. A typical range of values for I is 0.8 to 1.25.

3.8.2 Algorithm for 2005 NBCC Wind Loads

3.8.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the 2005 NBCC are based on Section 4.1.7.1 of the 2005 NBCC.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the load pattern, the user must include them manually.

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = I\, q\, C_g\, [C_{p\text{-winward}}\, C_{e\text{-windward}} + C_{p\text{-leeward}}\, C_{e\text{-leeward}}] \quad \text{(2005 NBCC 4.1.7.1(1))}$$

where,

I = Importance factor as input by the user.

q = Velocity pressure as input by the user.

C_g = Gust effect factor as input by the user.

$C_{p\text{-windward}}$ = External pressure coefficient for the windward wall as input by the user.

$C_{e\text{-windward}}$ = Exposure factor for the windward wall.

$C_{p\text{-leeward}}$ = External pressure coefficient for the leeward wall as input by the user.

$C_{e\text{-leeward}}$ = Exposure factor for the leeward wall.

$C_{e\text{-windward}}$ is determined from (2005 NBCC Eqn. 4.1.7.1(5).

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \quad \text{(2005 NBCC 4.1.7.1(5))}$$

$$C_{e\text{-windward}} = 0.7\left(\frac{h}{12}\right)^{0.3} \geq 0.7 \ \text{ for Rough Terrain} \qquad \text{(2005 NBCC 4.1.7.1(5))}$$

where,

    h =   Distance from the input bottom story/minimum level to the elevation considered, meters.

$C_{e\text{-leeward}}$ is determined from (2005 NBCC Eqn. 4.1.7.1(5).

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{0.2} \geq 0.9 \ \text{ for Open Terrain} \quad \text{(2005 NBCC 4.1.7.1(5))}$$

$$C_{e\text{-leeward}} = 0.7\left(\frac{h_{\text{middle}}}{12}\right)^{0.3} \geq 0.7 \ \text{for Rough Terrain}$$

$$\text{(2005 NBCC 4.1.7.1(5))}$$

where,

    h_{middle} =   One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1.

3.8.2.2 Exposure from Area Objects

Automatic wind loads for 2005 NBCC are based on Section 4.1.7.1 of the 2005 NBCC.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in 2005 NBCC Section 4.1.7.1.

The following equation is used to determine the wind pressure, p, at any point on the surface of the area objects.

    $p = I \, q \, C_e \, C_g \, C_p$ (2005 NBCC 4.1.7.1(1))

where,

I = Importance factor as input by the user.

q = Velocity pressure as input by the user.

C_e = Exposure factor.

C_g = Gust effect factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

C_e for a windward facing area object is determined from (2005 NBCC Eqn. 4.1.7.1(5)).

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \qquad (2005 \text{ NBCC } 4.1.7.1(5))$$

$$C_{e\text{-windward}} = 0.7\left(\frac{h}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} (2005 \text{ NBCC } 4.1.7.1(5))$$

where,

h = Distance from the input bottom story/minimum level to the elevation considered, meters.

C_e for a leeward facing area object is determined from (2005 NBCC Eqn. 4.1.7.1(5)).

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \quad (2005 \text{ NBCC } 4.1.7.1(5))$$

$$C_{e\text{-leeward}} = 0.7\left(\frac{h_{\text{middle}}}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain}$$

$$(2005 \text{ NBCC } 4.1.7.1(5))$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.9 2010 NBCC Wind Loads

3.9.1 Input Wind Coefficients

Three wind coefficients are input for 2010 NBCC wind loads. They are the velocity pressure, q, in kPa, the gust effect factor, C_g, and the importance factor, I.

The velocity pressure, q, can be obtained from 2010 NBCC Appendix C. A typical range of values for the velocity pressure is 0.27 to 1.23 kPa. Any positive value or zero is allowed.

The gust effect factor, C_g, is discussed in 2010 NBCC Section 4.1.7.1(6). The default value is 2.0. Any positive value is allowed.

The importance factor, I, is described in 2010 NBCC Table 4.1.7.1. A typical range of values for I is 0.8 to 1.25.

3.9.2 Algorithm for 2010 NBCC Wind Loads

3.9.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the 2010 NBCC are based on Section 4.1.7.1 of the 2010 NBCC.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the load pattern, the user must include them manually.

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = I\, q\, C_g\, [C_{p\text{-winward}}\, C_{e\text{-windward}} + C_{p\text{-leeward}}\, C_{e\text{-leeward}}] \quad (2010\ NBCC\ 4.1.7.1(1))$$

where,

I = Importance factor as input by the user.

q = Velocity pressure as input by the user.

C_g = Gust effect factor as input by the user.

$C_{p\text{-windward}}$ = External pressure coefficient for the windward wall as input by the user.

$C_{e\text{-windward}}$ = Exposure factor for the windward wall.

$C_{p\text{-leeward}}$ = External pressure coefficient for the leeward wall as input by the user.

$C_{e\text{-leeward}}$ = Exposure factor for the leeward wall.

$C_{e\text{-windward}}$ is determined from (2010 NBCC Eqn. 4.1.7.1(5) or may be specified by the user:

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \qquad (2010 \text{ NBCC } 4.1.7.1(5))$$

$$C_{e\text{-windward}} = 0.7\left(\frac{h}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} \quad (2010 \text{ NBCC } 4.1.7.1(5))$$

where,

h = Distance from the input bottom story/minimum level to the elevation considered, meters.

$C_{e\text{-leeward}}$ is determined from (2010 NBCC Eqn. 4.1.7.1(5) or may be specified by the user:

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \quad (2010 \text{ NBCC } 4.1.7.1(5))$$

$$C_{e\text{-leeward}} = 0.7\left(\frac{h_{\text{middle}}}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} \quad (2010 \text{ NBCC } 4.1.7.1(5))$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1.

3.9.2.2 Exposure from Area Objects

Automatic wind loads for 2010 NBCC are based on Section 4.1.7.1 of the 2010 NBCC.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in 2010 NBCC Section 4.1.7.1.

The following equation is used to determine the wind pressure, p, at any point on the surface of the area objects.

$$p = I\, q\, C_e\, C_g\, C_p \qquad\qquad \text{(2010 NBCC 4.1.7.1(1))}$$

where,

I = Importance factor as input by the user.

q = Velocity pressure as input by the user.

C_e = Exposure factor.

C_g = Gust effect factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

C_e for a windward facing area object is determined from (2010 NBCC Eqn. 4.1.7.1(5)) or may be specified by the user:

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{0.2} \ge 0.9 \ \text{ for Open Terrain} \qquad \text{(2010 NBCC 4.1.7.1(5))}$$

$$C_{e\text{-windward}} = 0.7\left(\frac{h}{12}\right)^{0.3} \ge 0.7 \ \text{ for Rough Terrain} \text{(2010 NBCC 4.1.7.1(5))}$$

where,

h = Distance from the input bottom story/minimum level to the elevation considered, meters.

C_e for a leeward facing area object is determined from (2010 NBCC Eqn. 4.1.7.1(5)) or may be specified by the user:

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \quad (2010 \text{ NBCC } 4.1.7.1(5))$$

$$C_{e\text{-leeward}} = 0.7\left(\frac{h_{\text{middle}}}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} \quad (2010 \text{ NBCC } 4.1.7.1(5))$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.10   2015 NBCC Wind Loads

3.10.1 Input Wind Coefficients

Three wind coefficients are input for 2015 NBCC wind loads. They are the velocity pressure, q, in kPa, the exposure factor, C_e, the topographic factor, C_t, the gust effect factor, C_g, and the importance factor, I_w.

The velocity pressure, q, can be obtained from 2015 NBCC Appendix C. A typical range of values for the velocity pressure is 0.27 to 1.05 kPa. Any positive value or zero is allowed.

The exposure factor, C_e, is discussed in 2015 NBCC Section 4.1.7.3(5). The exposure factor is either internally determined from terrain type or directly specified by the user. Any positive value is allowed when user specified.

The gust effect factor, C_t, is discussed in 2015 NBCC Section 4.1.7.4. The default value is 1.0. Any positive value is allowed.

The gust effect factor, C_g, is discussed in 2015 NBCC Section 4.1.7.3(10). The default value is 2.0. Any positive value is allowed.

The importance factor, I_w, is described in 2015 NBCC Table 4.1.7.3. A typical range of values for I_w is 0.8 to 1.25.

3.10.2 Algorithm for 2015 NBCC Wind Loads

3.10.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the 2015 NBCC are based on Section 4.1.7.3 of the 2015 NBCC.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the load pattern, the user must include them manually.

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = I_w \, q \, C_t \, C_g \, [C_{p\text{-winward}} \, C_{e\text{-windward}} + C_{p\text{-leeward}} \, C_{e\text{-leeward}}] \quad (2015 \text{ NBCC } 4.1.7.3(1))$$

where,

I_w = Importance factor as input by the user.

q = Velocity pressure as input by the user.

C_t = Topographic factor as input by the user.

C_g = Gust effect factor as input by the user.

$C_{p\text{-windward}}$ = External pressure coefficient for the windward wall as input by the user.

$C_{e\text{-windward}}$ = Exposure factor for the windward wall.

$C_{p\text{-leeward}}$ = External pressure coefficient for the leeward wall as input by the user.

$C_{e\text{-leeward}}$ = Exposure factor for the leeward wall.

$C_{e\text{-windward}}$ is determined from (2015 NBCC Eqn. 4.1.7.3(5)) or may be specified by the user:

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \qquad (2015 \text{ NBCC } 4.1.7.3(5))$$

$$C_{e\text{-windward}} = 0.7\left(\frac{h}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} \ (2015 \text{ NBCC } 4.1.7.3(5))$$

where,

h = Distance from the input bottom story/minimum level to the elevation considered, meters.

$C_{e\text{-leeward}}$ is determined from (2015 NBCC Eqn. 4.1.7.3(5)) or may be specified by the user:

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \quad (2015 \text{ NBCC } 4.1.7.1(5))$$

$$C_{e\text{-leeward}} = 0.7\left(\frac{h_{\text{middle}}}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} \ (2015 \text{ NBCC } 4.1.7.1(5))$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, P_x and P_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis. The program then combines the loads for each of the four wind load patterns described in NBCC 2015 Figure A-4.1.7.9(1), resulting in the permutations shown in Table 3-1.

Table 3-1: Wind Load Patterns

Case	Lateral Force	Torsional Moment
1	P_x	---
1	P_y	---
2	$0.75\,P_x$	$\pm 0.75\,e_1\,B_x\,P_x$
2	$0.75\,P_y$	$\pm 0.75\,e_1\,B_y\,P_y$
3	$0.75(P_x + P_y)$	---
4	$0.563(P_x + P_y)$	$\pm 0.563(e_1 B_x P_x \pm e_2 B_y P_y)$

where,

P_x = Resultant wind force in the *x*-direction.

P_y = Resultant wind force in the *y*-direction.

e_1 = Eccentricity for load in the direction of applied load as input by the user.

B_x = Diaphragm width in the *y*-direction.

e_2 = Eccentricity for load in the transverse direction of applied load as input by the user.

B_y = Diaphragm width in the *x*-direction.

3.10.2.2 Exposure from Area Objects

Automatic wind loads for 2015 NBCC are based on Section 4.1.7.3 of the 2015 NBCC.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in 2015 NBCC Section 4.1.7.3.

The following equation is used to determine the wind pressure, *p*, at any point on the surface of the area objects.

$$p = I_w\, q\, C_e\, C_t\, C_g\, C_p \qquad\qquad \text{(2015 NBCC 4.1.7.3(1))}$$

where,

I_w = Importance factor as input by the user.

q = Velocity pressure as input by the user.

C_e = Exposure factor.

C_t = Topographic factor as input by the user.

C_g = Gust effect factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

C_e for a windward facing area object is determined from (2015 NBCC Eqn. 4.1.7.3(5)) or may be specified by the user:

$$C_{e\text{-windward}} = \left(\frac{h}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \qquad (2015 \text{ NBCC } 4.1.7.3(5))$$

$$C_{e\text{-windward}} = 0.7\left(\frac{h}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain}(2015 \text{ NBCC } 4.1.7.3(5))$$

where,

h = Distance from the input bottom story/minimum level to the elevation considered, meters.

C_e for a leeward facing area object is determined from (2015 NBCC Eqn. 4.1.7.3(5)) or may be specified by the user:

$$C_{e\text{-leeward}} = \left(\frac{h_{\text{middle}}}{10}\right)^{0.2} \geq 0.9 \text{ for Open Terrain} \quad (2015 \text{ NBCC } 4.1.7.3(5))$$

$$C_{e\text{-leeward}} = 0.7\left(\frac{h_{\text{middle}}}{12}\right)^{0.3} \geq 0.7 \text{ for Rough Terrain} \quad (2015 \text{ NBCC } 4.1.7.1(5))$$

where,

h_{middle} = One-half of the distance from the input bottom story/minimum level to the input top story/maximum level, meters.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.11 ASCE 7-95 Wind Loads

3.11.1 Input Wind Coefficients

Five wind coefficients are input for ASCE 7-95 wind loads. They are the basic wind speed in miles per hour (mph), the exposure category, the wind importance factor, I, the topographic factor, K_{zt}, and the gust factor G.

The basic wind speed is described in ASCE 7-95 Section 6.5.2. A typical range of values for the basic wind speed is 85 to 150 mph.

The exposure categories are described in ASCE 7-95 Section 6.5.3. The exposure category can be A, B, C, or D. No other values are allowed.

The wind importance factor, I, is described in ASCE 7-95 Table 6-2. Note that the building and structure classification categories are defined in ASCE 7-95 Table 1-1. A typical range of values for I is 0.87 to 1.15.

The topographic factor K_{zt} is discussed in ASCE 7-95 Section 6.5.5. The default value for K_{zt} is 1.0. K_{zt} cannot be less than 1.0.

The gust response factor G is discussed in ASCE 7-95 Section 6.6. A typical range of values for G is 0.80 to 0.85.

3.11.2 Algorithm for ASCE 7-95 Wind Loads

3.11.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for ASCE 7-95 are based on Sections 6.4 through 6.6 of ASCE 7-95.

The wind loads applied are a modified version of those described in ASCE 7-95 Sections 6.4 through 6.6. Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of

roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the vertical projected area in pounds per square foot (psf).

$$q_z = 0.00256 \, K_z \, K_{zt} \, V^2 \, I \qquad \text{(ASCE 7-95 Eqn 6-1)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-95 Eqns. C3a and C3b).

K_{zt} = Topographic factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The velocity pressure exposure coefficient, K_z, is obtained using (Eqns. C3a and C3b in ASCE 7-95 Commentary Section 6.5.1).

$$K_z = 2.01 \left(\frac{z}{z_g} \right)^{2/\alpha} \quad \text{for 15 feet} \leq z \leq z_g$$

$$K_z = 2.01 \left(\frac{15}{z_g} \right)^{2/\alpha} \quad \text{for } z < 15 \text{ feet} \qquad \text{(ASCE 7-95 Eqns. C3a, C3b)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered.

z_g = As specified in Table 3-2 (ASCE 7-95 Table C6-2 in ASCE 7-95 Commentary Section 6.5.1).

α = As specified in Table 3-2 (ASCE 7-95 Table C6-2 in ASCE 7-95 Commentary Section 6.5.1).

Table 3-2: α and z_g factors for use in ASCE 7-95 Equations C3a and C3b

Exposure Category	α	z_g (feet)
A	5.0	1500
B	7.0	1200
C	9.5	900
D	11.5	700

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area, which is based on ASCE 7-95 Table 6-1. In particular, it is based on the row entitled "Main wind force-resisting systems" under the heading "Buildings of all heights."

$$p = q\, G\, C_{p\text{-windward}} + q_h\, G\, C_{p\text{-leeward}} \qquad \text{(ASCE 7-95 Table 6-1)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the horizontal projected area calculated using (ASCE 7-965 Eqn. 6-1).

G = Gust response factor as input by the user.

$C_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

q_h = Velocity pressure at the top story height on the surface of the vertical projected area calculated using (ASCE 7-965 Eqn. 6-1).

$C_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1.

3.11.2.2 Exposure from Area Objects

Automatic wind loads for ASCE 7-95 are based on Sections 6.4 through 6.6 of ASCE 7-95.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in ASCE 7-95 Section 6.4.2.

(ASCE 7-95 Eqn. 6-1) is used to determine the velocity pressure, q_z, at any height z on the surface of the user selected area objects in pounds per square feet (psf).

$$q_z = 0.00256 \, K_z \, K_{zt} \, V^2 \, I \qquad\qquad \text{(ASCE 7-95 Eqn. 6-1)}$$

where,

K_z = Velocity pressure exposure coefficient. See (ASCE 7-95 Eqns. C3a and C3b).

K_{zt} = Topographic factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

ASCE 7-95 Table 6-1 is used to determine the wind pressure, p, at any point on the surface of the area objects, which is based on ASCE 7-95 Table 6-1. In particular it is based on the row entitled "Main wind force-resisting systems" under the heading entitled "Buildings of all heights."

$$p = q \, G \, C_p \qquad\qquad \text{(ASCE 7-95 Table 6-1)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the area object calculated using (ASCE 7-95 Table 6-1). For leeward facing area objects, $q = q_h$, the velocity pressure at the top story/maximum height.

G = Gust response factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.12 ASCE 7-02 Wind Loads

3.12.1 Input Exposure

In addition to the items discussed in the section entitled "Exposure" earlier in this chapter, the automatic wind loads for ASCE 7-02 also offers the capability to generate wind loads on line (frame) objects for use on open or lattice structures. If the option to include frame objects is checked, wind loads will be generated on each line object that has been assigned wind parameters. The wind load pattern must be defined before assigning wind parameters to frame objects.

Assigning frame load open structure wind parameters allows specification of three items: the frame object is or is not loaded by wind (the default is that it is); the thickness of ice, if any; and the net force coefficient, C_f.

The ice thickness for wind load affects the area of the line object to be loaded, and has a default value of "Program Determined." The net force coefficient for wind, C_f, also has a default value of "Program Determined." The wind loads calculated at a line object are based on the elevation of the object, the dimensions of the object, and various code-dependent wind coefficients.

3.12.1.1 Input Wind Exposure Parameters

In addition to the items discussed in the section entitled "Wind Exposure Parameters" earlier in this chapter, the automatic wind loads for ASCE 7-02 allows specification of three additional coefficients when the exposure from extents of diaphragms is selected: the case type; and the eccentricity factors, e_1 and e_2.

The case types are described in ASCE 7-02 Figure 6-9. The case type can be 1, 2, 3, or 4.

The eccentricity factors are described in ASCE 7-02 Figure 6-9. A typical value for e_1 and e_2 is 0.15.

3.12.1.2 Input Pressure Coefficients

When the Input Pressure Coefficients option is *Program Determined*, pressure coefficients, C_p are taken from ASCE 7-02 Figure 6-6, Table for "Wall Pres-

sure Coefficients" in the windward and leeward directions. The determination of leeward pressure automatically accounts for the building aspect ratio *i.e.*, L/B ratio based on diaphragm extents. When the L/B ratio varies over the building height, the program uses the smallest L/B ratio for producing a maximum leeward pressure coefficient. If this effect is not desirable, the User Specified option provides an alternative way to overwrite the leeward pressure coefficients. A single load pattern with multi-step cases is sufficient for accurately capturing the variable leeward pressures with the Program Determined Option. For *User Specified* Input Pressure Coefficients option, only a single case in each specific direction is recommended.

3.12.1.3 Input Wind Coefficients

Seven or eight wind coefficients are input for ASCE 7-02 wind loads depending upon the type of exposure. They are the basic wind speed in miles per hour (mph), the exposure category, the wind importance factor, I, the topographic factor, K_{zt}, the gust factor, G, the directionality factor, k_d, the roughness length parameter, z_0, and the solid/gross area ratio if frame objects are exposed to wind loads.

The basic wind speed is described in ASCE 7-02 Section 6.5.4. A typical range of values for the basic wind speed is 85 to 150 mph.

The exposure categories are described in ASCE 7-02 Section 6.5.6.3. The exposure category can be A, B, C or D. No other values are allowed.

The wind importance factor, I, is described in ASCE 7-02 Table 6-1. Note that the building and structure classification categories are defined in ASCE 7-02 Table 1-1. A typical range of values for I is 0.77 to 1.15.

The topographic factor K_{zt} is discussed in ASCE 7-02 Section 6.5.7.2. The default value for K_{zt} is 1.0. K_{zt} cannot be less than 1.0.

The gust response factor G is discussed in ASCE 7-02 Section 6.5.8. A typical value for G is 0.85.

The directionality factor, K_d, is discussed in ASCE 7-02 Section 6.5.4.4. A typical range of values for K_d is 0.85 to 0.95.

The roughness length parameter, z_0, is discussed in ASCE 7-02 Commentary C6.5.6. A typical range of values for z_0 is 0.016 to 6.6.

The ratio of solid area to gross area, $\in$, is used in the determination of the net force coefficient, C_f, as discussed in ASCE 7-02 Section 6.5.13. This ratio applies only to open structures, and thus is available for user input only when exposure to frame objects has been selected.

3.12.2 Algorithm for ASCE 7-02 Wind Loads

3.12.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the ASCE 7-02 are based on Section 6.5 of ASCE 7-02.

The wind loads applied are a modified version of those described in ASCE 7-02 Section 6.5 (Method 2 – Analytical Procedure). Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the vertical projected area, in pounds per square foot (psf).

$$q_z = 0.00256 \, K_z \, K_{zt} \, K_d \, V^2 \, I \qquad \text{(ASCE 7-02 Eqn 6-15)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-02 Eqns. C6-3a and C6-3b).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The velocity pressure exposure coefficient, K_z, is obtained using (Eqns. C6-3a and C6-3b in ASCE 7-02 Commentary Section 6.5.6.4).

$$K_z = 2.01 \left(\frac{z}{z_g} \right)^{2/\alpha} \quad \text{for 15 feet} \leq z \leq z_g$$

$$K_z = 2.01 \left(\frac{15}{z_g} \right)^{2/\alpha} \quad \text{for } z < 15 \text{ feet} \qquad \text{(ASCE 7-02 C6-3a,C6-3b)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered.

z_g = Gradient height. See (ASCE 7-02 Eqn. C6-5).

α = Empirical exponent. See (ASCE 7-02 Eqn. C6-4).

The gradient height, z_g, is obtained using (Eqn. C6-5 in ASCE 7-02 Commentary Section 6.5.6.4).

$$z_g = 1273 \, z_0^{0.125} \qquad \text{(ASCE 7-02 C6-5)}$$

The empirical exponent α is obtained using (Eqn. C6-4 in ASCE 7-02 Commentary Section 6.5.6.4).

$$\alpha = 6.19 \, z_0^{-0.157} \qquad \text{(ASCE 7-02 C6-4)}$$

where,

z_0 = Roughness length parameter as input by the user.

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p \quad = \quad q \, G \, C_{p\text{-windward}} + q_h \, G \, C_{p\text{-leeward}} \qquad \text{(ASCE 7-02 Eqn 6-17)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the horizontal projected area calculated using (ASCE 7-02 Eqn. 6-15).

G = Gust response factor as input by the user.

$C_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

q_h = Velocity pressure at the top story height on the surface of the vertical projected area calculated using (ASCE 7-02 Eqn. 6-15).

$C_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis, as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, P_x and P_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis. The program then combines the loads for each of the four wind load patterns described in ASCE 7-02 Figure 6-9, resulting in the permutations shown in Table 3-3.

Table 3-3: Wind Load Patterns

CASE	Lateral Force	Torsional Moment
1	P_x	---
1	P_y	---
2	$0.75\,P_x$	$\pm 0.75\,e_1\,B_x\,P_x$
2	$0.75\,P_y$	$\pm 0.75\,e_1\,B_y\,P_y$
3	$0.75(P_x + P_y)$	---
4	$0.563(P_x + P_y)$	$\pm 0.563(e_1 B_x P_x \pm e_2 B_y P_y)$

where,

P_x = Resultant wind force in the x-direction.

P_y = Resultant wind force in the y-direction.

e_1 = Eccentricity for load in the direction of applied Wind load as input by the user.

B_x = Diaphragm width in the y-direction.

e_2 = Eccentricity for load in the transverse direction of applied load as input by the user.

B_y = Diaphragm width in the x-direction.

The design pressure for the parapet is determined by the following equation:

$$p_p \quad = \quad q_p \, G \, C_{pm} \qquad\qquad \text{(ASCE 7-02 Eqn. 6-20)}$$

where,

    p_p = Combined net pressure on the parapet due to the combination of net pressure from the front and back parapet surfaces.

    q_p = Velocity pressure evaluated at the top of the parapet

    GC_{pm} = Combined pressure coefficients

         = +1.8 psf for Windward parapet

         = −1.0 psf for Leeward parapet

3.12.2.2 Exposure from Area Objects

Automatic wind loads for the ASCE 7-02 are based on Section 6.5 of ASCE 7-02.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in ASCE 7-02 Section 6.5.12.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the user selected area objects, in pounds per square feet (psf).

$$q_z = 0.00256 \, K_z \, K_{zt} \, K_d \, V^2 \, I \qquad\qquad \text{(ASCE 7-02 Eqn. 6-15)}$$

where,

    K_z = The velocity pressure exposure coefficient. See (ASCE 7-02 Eqns. C6-3a and C6-3b).

    K_{zt} = Topographic factor as input by the user.

    K_d = Directionality factor as input by the user.

    V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The following equation is used to determine the wind pressure, p, at any point on the surface of the area objects.

$$p = q\, G\, C_p \qquad\qquad \text{(ASCE 7-02 Eqn. 6-17)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the area object calculated using (ASCE 7-02 Eqn. 6-15). For leeward facing area objects, $q = q_h$, the velocity pressure at the top story/maximum height.

G = Gust response factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.12.2.3 Exposure from Line (Frame) Objects

Automatic wind loads for the ASCE 7-02 are based on Section 6.5 of ASCE 7-02.

The wind loads applied when using the exposure from frame objects method are applied on the exposed surfaces of the user selected frame objects as described in ASCE 7-02 Section 6.5.13.

The following equation is used to determine the velocity pressure, q_z, at any height z on the projected area of the user selected frame objects, in pounds per square feet (psf).

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I \qquad\qquad \text{(ASCE 7-02 Eqn. 6-15)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-02 Eqns. C6-3a and C6-3b).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The following equation is used to determine the design wind force, F, on the surface of the frame objects.

$$F = q_z \, G \, C_f \, A_f \qquad \text{(ASCE 7-02 Eqn. 6-25)}$$

where,

q_z = Velocity pressure, q_z, evaluated at height z of the centroid of area A_f using (ASCE 7-02 Eqn. 6-15).

G = Gust response factor as input by the user.

C_f = Net force coefficient, as specified in Table 3-4 (ASCE 7-02 Figure 6-21).

A_f = Projected solid area normal to the wind.

Table 3-4: C_f factor for use in (ASCE 7-02 Eqn. 6-25)

Solid/Gross Area Ratio $\in$	C_f
< 0.1	2.0
0.1 to 0.29	1.8
0.3 to 0.7	1.6

3.13   2006 IBC / ASCE 7-05 Wind Loads

Section 1609.1.1 of the 2006 IBC states that wind loads shall be determined in accordance with ASCE Standard 7-05. For the sake of clarity, in the remainder of this section all references will be made only to the ASCE 7-05 document, with the understanding that this information is directly applicable to those using the 2006 IBC as well.

3.13.1 Input Exposure

In addition to the items discussed in the section entitled "Exposure" earlier in this chapter, the automatic wind loads for ASCE 7-05 allows specification of the generation of wind loads on line (frame) objects for use on open or lattice structures. If the option to include frame objects is checked, wind loads will be generated on each line object that has been assigned wind parameters. The wind load pattern must be defined before assigning wind parameters to frame objects.

Assigning frame load open structure wind parameters allows specification of three items: the frame object is or is not loaded by wind (the default is that it is); the thickness of ice, if any; and the net force coefficient, C_f.

The ice thickness for wind load affects the area of the line (frame) object to be loaded and has a default value of "Program Determined." The net force coefficient for wind, C_f, also has a default value of "Program Determined." The wind loads calculated at a line (frame) object are based on the elevation of the object, the dimensions of the object, and various code-dependent wind coefficients.

3.13.1.1 Input Wind Exposure Parameters

In addition to the items discussed in the section entitled "Wind Exposure Parameters" earlier in this chapter, the automatic wind loads for ASCE 7-05 also offers three additional coefficients to input when the exposure from extents of diaphragms is selected: the case type; and the eccentricity factors, e_1 and e_2.

The case types are described in ASCE 7-05 Figure 6-9. The case type can be 1, 2, 3, or 4.

The eccentricity factors are described in ASCE 7-05 Figure 6-9. A typical value for e_1 and e_2 is 0.15.

3.13.1.2 Input Pressure Coefficients

When the Input Pressure Coefficients option is *Program Determined*, pressure coefficients, C_p are taken from ASCE 7-05 Figure 6-6, Table for "Wall Pressure Coefficients" in the windward and leeward directions. The determination of leeward pressure automatically accounts for the building aspect ratio *i.e*., L/B ratio based on diaphragm extents. When L/B ratio varies over the building height, the program uses the smallest L/B ratio for producing a maximum leeward pressure coefficient. If this effect is not desirable, the User specified option provides an alternative way to overwrite the leeward pressure coefficients. A single load pattern with multi-step cases is sufficient for accurately capturing the variable leeward pressures with the Program Determined Option. For the *User Specified* Input Pressure Coefficients option, only a single case in each specific direction is recommended.

3.13.1.3 Input Wind Coefficients

Seven or eight wind coefficients are input for ASCE 7-05 wind loads, depending on the type of exposure. They are the basic wind speed in miles per hour (mph), the exposure category, the wind importance factor, I, the topographic factor, K_{zt}, the gust factor, G, the directionality factor, k_d, the roughness length parameter, z_0, and the solid/gross area ratio if frame objects are exposed to wind loads.

The basic wind speed is described in ASCE 7-05 Section 6.5.4. A typical range of values for the basic wind speed is 85 to 150 mph.

The exposure categories are described in ASCE 7-05 Section 6.5.6.3. The exposure category can be B, C, or D. No other values, including exposure A, are allowed.

The wind importance factor, I, is described in ASCE 7-05 Table 6-1. Note that the building and structure classification categories are defined in ASCE 7-05 Table 1-1. A typical range of values for I is 0.77 to 1.15.

The topographic factor K_{zt} is discussed in ASCE 7-05 Section 6.5.7.2. The default value for K_{zt} is 1.0. K_{zt} cannot be less than 1.0.

The gust effect factor G is discussed in ASCE 7-05 Section 6.5.8. A typical value for G is 0.85.

The directionality factor, K_d, is discussed in ASCE 7-05 Section 6.5.4.4. A typical range of values for K_d is 0.85 to 0.95.

The roughness length parameter, z_0, is discussed in ASCE 7-05 Commentary C6.5.6. A typical range of values for z_0 is 0.016 to 1.0.

The ratio of solid area to gross area, $\in$, is used in the determination of the net force coefficient, C_f, as discussed in ASCE 7-05 Section 6.5.15. This ratio applies only to open structures, and thus is available for user input only when exposure to frame objects has been selected.

3.13.2 Algorithm for ASCE 7-05 Wind Loads

3.13.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the ASCE 7-05 are based on Section 6.5 of ASCE 7-05.

The wind loads applied are a modified version of those described in ASCE 7-05 Section 6.5 (Method 2 – Analytical Procedure). Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the vertical projected area, in pounds per square foot (psf).

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I \qquad \text{(ASCE 7-05 Eqn. 6-15)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-05 Eqns. C6-4a and C6-4b).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The velocity pressure exposure coefficient, K_z, is obtained using (Eqns. C6-4a and C6-4b in ASCE 7-05 Commentary Section 6.5.6.6).

$$K_z = 2.01 \left(\frac{z}{z_g} \right)^{2/\alpha} \quad \text{for } 15 \text{ feet} \leq z \leq z_g$$

$$K_z = 2.01 \left(\frac{15}{z_g} \right)^{2/\alpha} \quad \text{for } z < 15 \text{ feet} \qquad \text{(ASCE 7-05 Eqn. C6-4a, C6-4b)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered.

z_g = Gradient height. See (ASCE 7-05 Eqn. C6-6).

α = Empirical exponent. See (ASCE 7-05 Eqn. C6-5).

The gradient height, z_g, and the empirical exponent α are obtained ASCE 7-05 Table 6-2.

ASCE 7-05 Eqn. 6-17 is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = q \, G \, C_{p\text{-windward}} + q_h \, G \, C_{p\text{-leeward}} \qquad \text{(ASCE 7-05 Eqn. 6-17)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the vertical projected area calculated using (ASCE 7-05 Eqn. 6-15).

G = Gust effect factor as input by the user.

$C_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

q_h = Velocity pressure at the top story height on the surface of the vertical projected area calculated using (ASCE 7-05 Eqn. 6-15).

$C_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, P_x and P_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis. The program then combines the loads for each of the four wind load patterns described in ASCE 7-05 Figure 6-9, resulting in the permutations shown in Table 3-5.

Table 3-5: Wind Load Patterns

Case	Lateral Force	Torsional Moment
1	P_x	---
1	P_y	---
2	$0.75\ P_x$	$\pm 0.75\ e_1\ B_x\ P_x$
2	$0.75\ P_y$	$\pm 0.75\ e_1\ B_y\ P_y$
3	$0.75(P_x + P_y)$	---
4	$0.563(P_x + P_y)$	$\pm 0.563(e_1 B_x P_x \pm e_2 B_y P_y)$

where,

P_x = Resultant wind force in the x-direction.

P_y = Resultant wind force in the y-direction.

e_1 = Eccentricity for load in the direction of applied load as input by the user.

B_x = Diaphragm width in the y-direction.

e_2 = Eccentricity for load in the transverse direction of applied load as input by the user.

B_y = Diaphragm width in the x-direction.

The design pressure for the parapet is determined by the following equation:

$$p_p = q_p\ G\ C_{pm} \qquad \text{(ASCE 7-05 Eqn. 6-20)}$$

where,

p_p = Combined net pressure on the parapet due to the combination of net pressure from the front and back parapet surfaces.

q_p = Velocity pressure evaluated at the top of the parapet

GC_{pm} = Combined pressure coefficients

= +1.5 psf for Windward parapet

= −1.0 psf for Leeward parapet

3.13.2.2 Exposure from Area Objects

Automatic wind loads for the ASCE 7-05 are based on Section 6.5 of ASCE 7-05.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in ASCE 7-05 Section 6.5.12.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the user selected area objects, in pounds per square feet (psf).

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I \qquad\qquad \text{(ASCE 7-05 Eqn. 6-15)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-05 Eqns. C6-4a and C6-4b).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The following equation is used to determine the wind pressure, p, at any point on the surface of the area objects.

$$p = q \, G \, C_p \qquad \text{(ASCE 7-05 Eqn. 6-17)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the area object calculated using (ASCE 7-05 Eqn. 6-15). For leeward facing area objects, $q = q_h$, the velocity pressure at the top story/maximum height.

G = Gust effect factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.13.2.3 Exposure from Line (Frame) Objects

Automatic wind loads for the ASCE 7-05 are based on Section 6.5 of ASCE 7-05.

The wind loads applied when using the exposure from frame objects method are applied on the exposed surfaces of the user selected frame objects as described in ASCE 7-05 Section 6.5.15.

The following equation is used to determine the velocity pressure, q_z, at any height z on the projected area of the user selected frame objects, in pounds per square feet (psf).

$$q_z = 0.00256 \, K_z \, K_{zt} \, K_d \, V^2 \, I \qquad \text{(ASCE 7-05 Eqn. 6-15)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-05 Eqns. C6-4a and C6-4b).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

I = Importance factor as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The following equation is used to determine the design wind force, F, on the surface of the frame objects.

$$F = q_z \, G \, C_f \, A_f \qquad\qquad \text{(ASCE 7-05 Eqn. 6-28)}$$

where,

q_z = Velocity pressure, q_z, evaluated at height z of the centroid of area A_f using ASCE 7-05 Eqn. 6-15.

G = Gust effect factor as input by the user.

C_f = Net force coefficient, as specified in Table 3-6 (ASCE 7-05 Figure 6-22).

A_f = Projected solid area normal to the wind.

Table 3-6: C_f factor for use in ASCE 7-05 Equation 6-28

Solid/Gross Area Ratio $\in$	C_f
< 0.1	2.0
0.1 to 0.29	1.8
0.3 to 0.7	1.6

3.14 ASCE 7-10 Wind Loads

3.14.1 Input Exposure

In addition to the items discussed in the section entitled "Exposure" earlier in this chapter, the automatic wind loads for ASCE 7-10 allows specification of the generation of wind loads on line (frame) objects for use on open or lattice structures. If the option to include frame objects is checked, wind loads will be generated on each line object that has been assigned wind parameters. The

wind load pattern must be defined before assigning wind parameters to frame objects.

Assigning frame load open structure wind parameters allows specification of three items: the frame object is or is not loaded by wind (the default is that it is); the thickness of ice, if any; and the net force coefficient, C_f.

The ice thickness for wind load affects the area of the line object to be loaded and has a default value of "Program Determined." The net force coefficient for wind, C_f, also has a default value of "Program Determined." The wind loads calculated at a line object are based on the elevation of the object, the dimensions of the object, and various code-dependent wind coefficients.

3.14.1.1 Input Wind Exposure Parameters

In addition to the items discussed in the section entitled "Wind Exposure Parameters" earlier in this chapter, the automatic wind loads for ASCE 7-10 also offers three additional coefficients to input when the exposure from extents of diaphragms is selected: the case type; and the eccentricity factors, e_1 and e_2.

The case types are described in ASCE 7-10 Figure 27.4-8. The case type can be 1, 2, 3, or 4.

The eccentricity factors are described in ASCE 7-10 Figure 27.4-8. A typical value for e_1 and e_2 is 0.15.

3.14.1.2 Input Pressure Coefficients

When the Input Pressure Coefficients option is *Program Determined*, pressure coefficients, C_p are taken from ASCE 7-10 Figure 27.4-1, Table for "Wall Pressure Coefficients" in the windward and leeward directions. The determination of the leeward pressure automatically accounts for the building aspect ratio *i.e*., L/B ratio based on diaphragm extent. When the L/B ratio varies over the building height, the program uses the smallest L/B ratio for producing a maximum leeward pressure coefficient. If this effect is not desirable, the User specified option provides an alternative way to overwrite the leeward pressure coefficients. A single load pattern with multi-step cases is sufficient for accurately capturing the variable leeward pressures with the Program Determined Option. For the *User Specified* Input Pressure Coefficients option, only a single case in each specific direction is recommended.

3.14.1.3 Input Wind Coefficients

Seven or eight wind coefficients are input for ASCE 7-10 wind loads, depending on the type of exposure. They are the basic wind speed in miles per hour (mph), the exposure category, the topographic factor, K_{zt}, the gust factor, G, the directionality factor, k_d, and the solid/gross area ratio if frame objects are exposed to wind loads

The basic wind speed is described in ASCE 7-10 Section 26.5.1. A typical range of values for the basic wind speed is 85 to 150 mph.

The exposure categories are described in ASCE 7-10 Section 26.7.3. The exposure category can be B, C, or D. No other values, including exposure A, are allowed.

The topographic factor K_{zt} is discussed in ASCE 7-10 Section 26.8.1. The default value for K_{zt} is 1.0. K_{zt} cannot be less than 1.0.

The gust effect factor G is discussed in ASCE 7-10 Section 26.9.1. A typical value for G is 0.85.

The directionality factor, K_d, is discussed in ASCE 7-10 Section 26.6. A typical range of values for K_d is 0.85 to 0.95.

The ratio of solid area to gross area, $\in$, is used in the determination of the net force coefficient, C_f, as discussed in ASCE 7-10 Section 29.5. This ratio applies to open structures only and thus is available for user input only when exposure to frame objects has been selected.

3.14.2 Algorithm for ASCE 7-10 Wind Loads

3.14.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the ASCE 7-10 are based on Section 27.2 of ASCE 7-10.

The wind loads applied are a modified version of those described in ASCE 7-10 Section 27.2, Part 1 for Enclosed, Partially Enclosed, and Open Building of all heights. Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind

loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the vertical projected area, in pounds per square foot (psf).

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2 \qquad\text{(ASCE 7-10 Eqn. 27.3-1)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-10 Eqns. 27.3.1).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

The velocity pressure exposure coefficient, K_z, is obtained using Table 27.3-1, Eqns. C27.3-1 and C27.3-2 in ASCE 7-10 Commentary.

$$K_z = 2.01 \left(\frac{z}{z_g} \right)^{2/\alpha} \quad \text{for } 15 \text{ feet} \leq z \leq z_g$$

$$K_z = 2.01 \left(\frac{15}{z_g} \right)^{2/\alpha} \quad \text{for } z < 15 \text{ feet} \qquad \text{(ASCE 7-10 Eqn. 27.3.1)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered.

z_g = Gradient height.

α = Empirical exponent.

The gradient height, z_g, and the empirical exponent α are obtained using ASCE 7-10 Table 26.9-1.

ASCE 7-10 Eqn. 27.4-2 is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = q \, G \, C_{p\text{-windward}} + q_h \, G \, C_{p\text{-leeward}} \qquad \text{(ASCE 7-10 Eqn. 27.4-2)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the vertical projected area calculated using (ASCE 7-10 Section 27.4.1).

G = Gust effect factor as input by the user.

$C_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

q_h = Velocity pressure at the top story height on the surface of the vertical projected area calculated using (ASCE 7-10 Section 27.4.1).

$C_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, P_x and P_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis. The program then combines the loads for each of the four wind load patterns described in ASCE 7-10 Figure 27.4-8, resulting in the permutations shown in Table 3-7.

Table 3-7: Wind Load Patterns

Case	Lateral Force	Torsional Moment
1	P_x	---
1	P_y	---
2	$0.75 \, P_x$	$\pm 0.75 \, e_1 \, B_x \, P_x$
2	$0.75 \, P_y$	$\pm 0.75 \, e_1 \, B_y \, P_y$
3	$0.75(P_x + P_y)$	---
4	$0.563(P_x + P_y)$	$\pm 0.563(e_1 B_x P_x \pm e_2 B_y P_y)$

where,

P_x = Resultant wind force in the *x*-direction.

P_y = Resultant wind force in the *y*-direction.

e_1 = Eccentricity for load in the direction of applied load as input by the user.

B_x = Diaphragm width in the *y*-direction.

e_2 = Eccentricity for load in the transverse direction of applied load as input by the user.

B_y = Diaphragm width in the *x*-direction.

The design pressure for the parapet is determined by the following equation:

$$p_p \quad = \quad q_p \, G \, C_{pm} \qquad\qquad \text{(ASCE 7-10 Eqn. 27.4-4)}$$

where,

p_p = Combined net pressure on the parapet due to the combination of net pressure from the front and back parapet surfaces.

q_p = Velocity pressure evaluated at the top of the parapet

GC_{pm} = Combined pressure coefficients

= +1.5 psf for Windward parapet

= −1.0 psf for Leeward parapet

3.14.2.2 Exposure from Area Objects

Automatic wind loads for the ASCE 7-10 are based on Section 27.2 of ASCE 7-10.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in ASCE 7-10 Section 27.2.

The following equation is used to determine the velocity pressure, q_z, at any height z on the surface of the user selected area objects, in pounds per square feet (psf).

$$q_z \;=\; 0.00256 \; K_z \, K_{zt} \, K_d \, V^2 \qquad \text{(ASCE 7-10 Eqn. 27.3-1)}$$

where,

K_z = The velocity pressure exposure coefficient. See (ASCE 7-10 Eqns. Section 27.3-1).

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The following equation is used to determine the wind pressure, p, at any point on the surface of the area objects.

$$p \;=\; q \, G \, C_p \qquad \text{(ASCE 7-10 Eqn. 27.4-2)}$$

where,

q = Velocity pressure, q_z, at any height z on the surface of the area object calculated using (ASCE 7-10 Eqn. 27.4-2). For leeward facing area objects, $q = q_h$, the velocity pressure at the top story/maximum height.

G = Gust effect factor as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.14.2.3 Exposure from Line (Frame) Objects

Automatic wind loads for the ASCE 7-10 are based on Section 29.5 of ASCE 7-10.

The wind loads applied when using the exposure from frame objects method are applied on the exposed surfaces of the user selected frame objects as described in ASCE 7-10 Section 27.3-1.

The following equation is used to determine the velocity pressure, q_z, at any height z on the projected area of the user selected frame objects, in pounds per square feet (psf).

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2 \qquad\qquad \text{(ASCE 7-10 Eqn. 29.3-1)}$$

where,

K_z = The velocity pressure exposure coefficient.

K_{zt} = Topographic factor as input by the user.

K_d = Directionality factor as input by the user.

V = Basic wind speed in miles per hour (mph) as input by the user.

The value for K_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The following equation is used to determine the design wind force, F, on the surface of the frame objects.

$$F = q_z\, G\, C_f\, A_f \qquad\qquad \text{(ASCE 7-10 Eqn. 29.5-1)}$$

where,

q_z = Velocity pressure, q_z, evaluated at height z of the centroid of area A_f using ASCE 7-10 Eqn. 29.3-1.

G = Gust effect factor as input by the user.

C_f = Net force coefficient, as specified in Table 3-8 (ASCE 7-10 Figure 29.5-2).

A_f = Projected solid area normal to the wind.

Table 3-8: C_f factor for use in ASCE 7-10 Equation 29.5-1

Solid/Gross Area Ratio	C_f

$\in$	
< 0.1	2.0
0.1 to 0.29	1.8
0.3 to 0.7	1.6

3.15   1987 RCDF Wind Loads

3.15.1 Input Wind Coefficients

A single wind coefficient, the wind velocity, V_D, is input for 1987 Reglamento de Construcciones para el Distrito Federal (RCDF) wind loads.

The wind velocity is described in 1987 RCDF Section 3.1.

3.15.2 Algorithm for 1987 RCDF Wind Loads

3.15.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the 1987 RCDF are based on Section 3 of the Normas Tecnicas Complementarias para Diseno por Viento.

The wind loads applied when using the exposure from extents of diaphragms method are based on a modified version of the Metodos Simplificado (Simplified Method) as described in Section 3 of the 1987 RCDF. Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

(Eqn. 3-1) is used to determine the wind pressure, p_z, at any point on the surface of the vertical projected area in pascals (Pa). (Eqn. 3-1) is based on (1987 RCDF Normas Tecnicas Complementarias para Diseno por Viento Eqn. 3.3).

$$p_z = 0.47\, V_D^2 \left(C_{p\text{-windward}} + C_{p\text{-leeward}} \right) \qquad \text{(Eqn. 3-1)}$$

where,

V_D = Wind velocity as input by the user.

$C_{p\text{-windward}}$ = Windward pressure coefficient as input by the user.

$C_{p\text{-leeward}}$ = Leeward pressure coefficient as input by the user.

The programs distribute the pressures, p_z, on the surface of the vertical project-ed area to each diaphragm on a tributary area basis, as shown in Figure 3-1.

3.15.2.2 Exposure from Area Objects

Automatic wind loads for the 1987 RCDF are based on Section 3 of the Nor-mas Tecnicas Complementarias para Diseno por Viento.

The wind loads applied when using the exposure from area objects method are based on Metodos Simplificado (Simplified Method) as described in Section 3 of the 1987 RCDF. Wind loads are applied on the vertical and horizontal sur-faces of the user selected area objects as described in Section 3.

(Eqn. 3-2) is used to determine the wind pressure, p_z, at any point on the sur-face of the area objects in pascals (Pa). (Eqn. 3-2) is based on (1987 RCDF Normas Tecnicas Complementarias para Diseno por Viento Eqn. 3.3).

$$p_z = 0.47 \ C_p \ V_D^2 \qquad\qquad \text{(Eqn. 3-2)}$$

where,

V_D = Wind velocity as input by the user.

C_p = Windward or leeward external pressure coefficient assigned to the area object by the user.

The programs distribute the pressures, p_z, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.16 2010 Chinese Wind Loads

3.16.1 Input Wind Exposure Parameters

In addition to the wind direction angle discussed in the section entitled "Wind Exposure Parameters" earlier in this chapter, two additional coefficients are input for the automatic wind loads for 2010 Chinese when the exposure from extents of diaphragms is selected: the building width, *B*, and the shape

coefficient, μ_s. The building width, *B*, is also input when the exposure from area objects is selected.

The building windward width, *B*, is used in determining the wind vibration coefficient β_z, from the GB50009-2012 (Eqn. 8.4.3).

The shape coefficient for wind load, μ_s, replaces the windward and leeward coefficients previously discussed in this chapter. This coefficient is described in section 8.3 of GB50009-2012.

When the exposure from extents of diaphragms is selected and across wind or torsion wind option is selected: building depth D is input. For across wind, corner modification ratio b/B and lateral period are input. For torsion wind, torsion period is input.

3.16.2 Input Wind Coefficients

Two wind coefficients are input for 2010 Chinese wind loads: the basic wind pressure, w_0, in kN per meter^2 (kN/m^2); and the ground roughness type, *RT*.

The basic wind pressure is described in GB5009-2010 appendix E.

The ground roughness types are described in GB50009-2012 Section 8.2. The roughness type can be A, B, C, or D. No other values are allowed.

3.16.2.1 Input Phi Z Source

Two choices are offered for determining how the mode coefficient, φ_z, shall be calculated by the program. The first mode of vibration coefficient can be obtained from a modal analysis or by using the *Z/H* ratio.

3.16.2.2 Input T_1 Source

The fundamental period, T_1, may be determined by the program from a modal analysis, or it may be input directly by the user.

3.16.2.3 Input Other Parameters

The damping ratio, ζ, is input for the 2010 Chinese wind loads for use in calculating the fluctuating wind load resonance factor.

3.16.3 Algorithm for 2010 Chinese Wind Loads

3.16.3.1 Exposure from Extents of Diaphragms

Automatic wind loads for the 2010 Chinese are based on GB 50009-2012 section 8 and appendix H.

Along wind loads, when using the exposure from extents of diaphragms method, are applied on the vertical projected area as determined based on the story heights and the input exposure widths for each diaphragm. Wind vibration coefficient, β_z at height z is determined by:

$$\beta_z = 1 + 2g\,I_{10}\,B_z\,\sqrt{1 + R^2} \qquad \text{(GB50009-2012 Eqn.8.4.3)}$$

where,

g = peak factor, g=2.5.

I_{10} = turbulence intensity at 10m. For roughness type A, B, C, and D, values are 0.12, 0.14, 0.23 and 0.39 correspondingly.

R = fluctuating wind load resonance factor.   (GB50009-2012 8.4.4)

B_z = fluctuating wind load background factor.   (GB50009-2012 8.4.5)

The wind pressure, w_k (in kN/m^2), at any point on the surface of the vertical projected area, is determined by:

$$w_k = \beta_z\mu_s\mu_z w_0 \qquad \text{(GB50009-2012 Eqn. 8.1.1-1)}$$

where,

β_z = wind vibration coefficient at height z.

μ_s = shape coefficient for wind load as input by the user.

μ_z = wind pressure distribution coefficient at height z (table 7.2.1 GB 50009-2012).

w_0 = basic value for wind pressure as input by the user.

The across wind pressure, w_{Lk} (in kN/m^2), at any point on the surface of the vertical projected area, is determined by:

$$w_{Lk} = g \, w_0 \, \mu_z C'_L \sqrt{1 + R_L^2} \qquad \text{(GB50009-2012 Eqn. H2.2)}$$

where,

$\quad C'_L =$ across wind coefficient. $\qquad$ (GB50009-2012 H.2.3)

$\quad R_L \ =$ across wind resonance factor. $\qquad$ (GB50009-2012 H.2.4)

Corner modification ratio b/B is used for calculating RL, positive value means chamfer corner, negative value means concave corner. $0.05 \leq b/B \leq 0.2$.

The torsion wind pressure, w_{Tk} (in kN/m^2), at any point on the surface of the vertical projected area, is determined by:

$$w_{Tk} = 1.8g \, w_0 \, \mu_H C'_T \left(\frac{z}{H} \right)^{0.9} \sqrt{1 + R_T^2} \qquad \text{(GB50009-2012 Eqn. H.3.2)}$$

where,

$\quad \mu_H \ =$ wind pressure distribution coefficient at structure top.

$\quad C'_T =$ torsion wind induced coefficient. $\qquad$ (GB50009-2012 H.3.3)

$\quad R_T \ =$ torsion wind resonance factor. $\qquad$ (GB50009-2012 H.3.4)

The programs distribute the pressures, w_k, w_{Lk} and w_{Tk}, on the surface of the vertical projected area to each diaphragm on a tributary area basis, as shown in Figure 3-1.

If across wind load option selected, the program automatically create sub step $0.6F_{Dk} \pm F_{Lk}$ for across wind load case, where F_D is along wind action, F_{Lk} is across wind action. If torsion wind load option selected, the program automatically create torsion wind load sub step. Only rectangular structure plan shape is considered for across wind effect.

3.16.3.2 Exposure from Area Objects

Automatic wind loads for the 2010 Chinese are based on Section 3.2 of the JGJ 3-2002 and Section 7 of GB 50009-2001.

The wind loads applied when using the exposure from area objects method are as described in Section 8 of GB 50009-2001. Wind loads are applied on the vertical and horizontal surfaces of the user selected area objects.

The wind pressure, w_k (in kN/m^2), at any point on the surface of the vertical projected area, is determined by:

$$w_k = \beta_z \mu_s \mu_z w_0 \qquad\qquad \text{(GB50009-2012 Eqn. 8.1.1-1)}$$

where,

β_z = wind vibration coefficient at height z.

μ_s = shape coefficient for wind load as input by the user.

μ_z = wind pressure distribution coefficient at height z (table 7.2.1 GB 50009-2012).

w_0 = basic value for wind pressure as input by the user.

The value for β_z is the same as described in the previous section entitled "Exposure from Extents of Diaphragms."

The programs distribute the pressures, w_k, on the surface of each area object, which in turn creates loads on the joints connected to the area objects. As a general rule, only area objects exposed on the windward side of the building should be loaded using the exposure from area objects method when using the 2010 Chinese automatic wind load option.

3.17   2008 API 4F Wind Loads

Two wind coefficients are input for 2008 API 4F wind loads. They are the reference wind speed in knots and the Structural Safety Level (SSL) Multiplier.

3.17.1 Input Exposure

In addition to the items discussed in the section entitled "Exposure" earlier in this chapter, the automatic wind loads for API 4F-2008 allows specification of the generation of wind loads on line (frame) objects for use on open or lattice structures. If the option to include frame objects is checked, wind loads will be generated on each line object that has been assigned wind parameters. The wind load pattern must be defined before assigning wind parameters to frame objects.

Assigning frame load open structure wind parameters allows specification of three items: the frame object is or is not loaded by wind (the default is that it is); the thickness of ice, if any; and the net force coefficient, C_s.

The ice thickness for wind load affects the area of the line object to be loaded, and has a default value of "Program Determined." The net force coefficient for wind, C_s, also has a default value of "Program Determined." The wind loads calculated at a line object are based on the elevation of the object, the dimensions of the object, and various code-dependent wind coefficients.

3.17.2 Algorithm for API 4F-2008 Wind Loads

3.17.2.1 Exposure from Area Objects

Automatic wind loads for the API 4F-2008 are based on Section 8.3 of API Specification 4F.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in API 4F-2008 Section 8.3.3.

The following equation is used to determine the velocity pressure, q_m, at any height z on the surface of the user selected area objects, in pounds per square feet (psf).

$$q_m = 0.00338 \, K_i \, C_p \, V_z^2 \qquad \text{(API 4F-2008 Section 8.3.3)}$$

where,

K_i = This factor is taken as 1.0,

C_p = Wind pressure coefficient,

V_z = Wind speed in knots at height z as computed by API 4F-2008 section 8.3.1.3.

The following equation is used to determine the wind speed, V_z, at any point on the surface of the area objects.

$$V_z = V_{des}\,\beta \qquad\qquad \text{(API 4-2008 Section 8.3.1.3)}$$

where

$$\beta = \sqrt{0.85} \qquad\qquad \text{for heights} \leq 4.6 \text{ m (15 ft)}$$

$$\beta = \sqrt{2.01\left(z/900\right)^{0.211}} \qquad \text{for heights} > 4.6 \text{ m (15 ft)}$$

and

$$V_{des} = V_{ref}\,\alpha_{ref} \qquad\qquad \text{(API 4-2008 Section 8.3.1.1 and 8.3.1.2)}$$

where,

V_{des} = Maximum design Wind velocity.

β = Elevation factor as determine from API 4F-2008 Table 8.4.

α_{ref} = Structural Safety Level (SSL) Multiplier as input by the user.

The programs distribute the pressures, q_m, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.17.2.2 Exposure from Line (Frame) Objects

Automatic wind loads for the API 4F-2008 are based on Section 8.3 of API Specification 4F.

The wind loads applied when using the exposure from frame objects method are applied on the exposed surfaces of the user selected frame objects as described in API 4F-2008 Section 8.3.3.

The following equation is used to determine the velocity pressure, q_m, at any height z on the projected area of the user selected frame objects, in pounds per square feet (psf).

$$q_m = 0.00338 \, K_i \, C_s \, V_z^2 \qquad\qquad \text{(API 4F-2008 Section 8.3.3)}$$

where,

K_i = A factor to account for angle of inclination ϕ between the longitudinal axis of an individual area and the wind.

C_s = Shape coefficient in accordance with clause API 4F-2008 8.3.3.4 and Table 8.6.

V_z = Wind speed in knots at height z as computed by API 4F-2008 section 8.3.1.3.

The following equation is used to determine the wind speed, V_z, at any point on the surface of the area objects.

$$V_z = V_{des} \, \beta \qquad\qquad \text{(API 4-2008 Section 8.3.1.3)}$$

where

$$\beta = \sqrt{0.85} \qquad\qquad \text{for heights} \le 4.6 \text{ m (15 ft)}$$

$$\beta = \sqrt{2.01 \left(z / 900 \right)^{0.211}} \qquad \text{for heights} > 4.6 \text{ m (15 ft)}$$

and

$$V_{des} = V_{ref} \, \alpha_{ref} \qquad\qquad \text{(API 4-2008 Section 8.3.1.1 and 8.3.1.2)}$$

where,

V_{des} = Maximum design Wind velocity.

β = Elevation factor as determine from API 4F-2008 Table 8.4.

α_{ref} = Structural Safety Level (SSL) Multiplier as input by the user.

The following equation is used to determine the member design wind force, F_m, on the surface of the frame objects.

$$F_m = q_m \, C_s \, A \qquad\qquad \text{(API 4F-2008 Section 8.3.3)}$$

A correction factor K_{sh} is used to account for global shielding effects and for changes in airflow around member or appurtenances ends. The K_{sh} factor applies to the overall wind load on the building, but does not apply to the load on the member itself.

$$F_t = G_f \, K_{sh} \sum F_m \qquad\qquad \text{(API 4F-2008 Section 8.3.3)}$$

where,

G_f = Gust effect factor to account for spatial coherence in accordance with API 4F section 8.3.3.3.

K_{sh} = A reduction factor to account for global shielding by members or appurtenances, and for changes in airflow around member or appurtenance in accordance with API 4F section 8.3.3.3

q_m = Velocity pressure, q_m, evaluated at height z of the centroid of area A_f.

C_s = Shape coefficient, as specified in Table 3-9 (API 4F-2008, Table 8.6).

A = Projected solid area normal to the wind.

Table 3-9: C_s Shape Coefficients for use in (API 4F-2008)

Shape	C_s
Angles, Channels, Beams, Tees	1.8
Square/Rectangular box	1.5
Round pipes	0.8
Others	2.0

3.18   2013 API 4F Wind Loads

Two wind coefficients are input for 2013 API 4F wind loads. They are the reference wind speed in knots and the Structural Safety Level (SSL) Multiplier.

3.18.1 Input Exposure

In addition to the items discussed in the section entitled "Exposure" earlier in this chapter, the automatic wind loads for API 4F-2013 allows specification of the generation of wind loads on line (frame) objects for use on open or lattice structures. If the option to include frame objects is checked, wind loads will be generated on each line object that has been assigned wind parameters. The wind load pattern must be defined before assigning wind parameters to frame objects.

Assigning frame load open structure wind parameters allows specification of three items: the frame object is or is not loaded by wind (the default is that it is); the thickness of ice, if any; and the net force coefficient, C_s.

The ice thickness for wind load affects the area of the line object to be loaded, and has a default value of "Program Determined." The net force coefficient for wind, C_s, also has a default value of "Program Determined." The wind loads calculated at a line object are based on the elevation of the object, the dimensions of the object, and various code-dependent wind coefficients.

3.18.2 Algorithm for API 4F-2013 Wind Loads

3.18.2.1 Exposure from Area Objects

Automatic wind loads for the API 4F-2013 are based on Section 8.3 of API Specification 4F.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects as described in API 4F-2013 Section 8.3.3.

The following equation is used to determine the velocity pressure, q_m, at any height z on the surface of the user selected area objects, in pounds per square feet (psf).

$$q_m = 0.00338 \, K_i \, C_p \, V_z^2 \qquad \text{(API 4F-2013 Section 8.3.3)}$$

where,

K_i = This factor is taken as 1.0,

C_p = Wind pressure coefficient,

V_z = Wind speed in knots at height z as computed by API 4F-2013 section 8.3.1.3.

The following equation is used to determine the wind speed, V_z, at any point on the surface of the area objects.

$$V_z = V_{\text{des}} \, \beta \qquad \text{(API 4-2013 Section 8.3.1.4)}$$

where

$$\beta = \sqrt{0.85} \qquad \text{for heights} \le 4.6 \text{ m (15 ft)}$$

$$\beta = \sqrt{2.01\left(\frac{z}{900}\right)^{0.211}} \qquad \text{for heights} > 4.6 \text{ m (15 ft)}$$

and

$$V_{des} = V_{ref}\, \alpha_{ref} \qquad \text{(API 4-2013 Section 8.3.1.2 and 8.3.1.3)}$$

where,

V_{des} = Maximum design Wind velocity.

β = Elevation factor as determine from API 4F-2013 Table 6.

α_{ref} = Structural Safety Level (SSL) Multiplier as input by the user.

The programs distribute the pressures, q_m, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.18.2.2 Exposure from Line (Frame) Objects

Automatic wind loads for the API 4F-2013 are based on Section 8.3 of API Specification 4F.

The wind loads applied when using the exposure from frame objects method are applied on the exposed surfaces of the user selected frame objects as described in API 4F-2013 Section 8.3.3.

The following equation is used to determine the velocity pressure, q_m, at any height z on the projected area of the user selected frame objects, in pounds per square feet (psf).

$$q_m = 0.00338\, K_i\, C_s\, V_z^2 \qquad \text{(API 4F-2013 Section 8.3.3)}$$

where,

K_i = A factor to account for angle of inclination ϕ between the longitudinal axis of an individual area and the wind.

C_s = Shape coefficient in accordance with clause API 4F-2013 8.3.3.5 and Table 8.

V_z = Wind speed in knots at height z as computed by API 4F-2013 section 8.3.1.4.

The following equation is used to determine the wind speed, V_z, at any point on the surface of the area objects.

$$V_z = V_{des}\, \beta \qquad\qquad \text{(API 4-2013 Section 8.3.1.4)}$$

where

$$\beta = \sqrt{0.85} \qquad\qquad \text{for heights} \leq 4.6 \text{ m (15 ft)}$$

$$\beta = \sqrt{2.01\left(z/900\right)^{0.211}} \qquad \text{for heights} > 4.6 \text{ m (15 ft)}$$

and

$$V_{des} = V_{ref}\, \alpha_{ref} \qquad\qquad \text{(API 4-2013 Section 8.3.1.2 and 8.3.1.3)}$$

where,

V_{des} = Maximum design Wind velocity.

β = Elevation factor as determine from API 4F-2013 Table 6.

α_{ref} = Structural Safety Level (SSL) Multiplier as input by the user.

The following equation is used to determine the member design wind force, F_m, on the surface of the frame objects.

$$F_m = q_m\, C_s\, A \qquad\qquad \text{(API 4F-2013 Section 8.3.3)}$$

A correction factor K_{sh} is used to account for global shielding effects and for changes in airflow around member or appurtenances ends. The K_{sh} factor applies to the overall wind load on the building, but does not apply to the load on the member itself.

$$F_t = G_f\, K_{sh} \sum F_m \qquad\qquad \text{(API 4F-2013 Section 8.3.3)}$$

where,

G_f = Gust effect factor to account for spatial coherence in accordance with API 4F section 8.3.3.4

K_{sh} = A reduction factor to account for global shielding by members or appurtenances, and for changes in airflow around member or appurtenance in accordance with API 4F section 8.3.3.4

q_m = Velocity pressure, q_m, evaluated at height z of the centroid of area A_f.

C_s = Shape coefficient, as specified in Table 3-10 (API 4F-2013, Table 1).

A = Projected solid area normal to the wind.

Table 3-10: C_s Shape Coefficients for use in (API 4F-2013)

Shape	C_s
Angles, Channels, Beams, Tees	1.8
Square/Rectangular box	1.5
Round pipes	0.8
Others	2.0

3.19 2005 Eurocode 1(EN 1991-1-4) Wind Loads

3.19.1 Input Wind Coefficients

Seven wind coefficients are input for EN 1991-1-4:2005 wind loads. They are the basic wind speed, v_b, in meter per second (m/sec), the terrain category, the terrain orography, $c_o(z)$, turbulence factor, k_1, and the structural factor, $c_s c_d$.

The basic wind velocity, v_b, is described in EN 1991-1-4:2005 Section 4.2 (2)P.

The terrain roughness, $C_r(z)$, is described in EN 1991-1-4:2005 Section 4.3.2. The terrain categories can be 0, I, II, III and IV. The roughness factor, $C_r(z)$, accounts for the variability of the mean wind velocity at the site of the structure due to:

- the height of ground level

- the ground roughness of the terrain upwind of the structure in the wind direction considered

The terrain orography, $c_o(z)$, is described in EN 1991-1-4:2005 Section 4.3.3. The orography factor is taken as 1.0 unless otherwise specified in EN 1991-1-4:2005 Section 4.3.3.

The wind turbulence factor k_1 is discussed in EN 1991-1-4:2005 Section 4.4.

The roughness length parameter, z_0, is discussed in EN 1991-1-4:2005 Section 4.3.2, Table 4.1. A typical range of values for z_0 is 0.003 to 1.0.

3.19.2 Algorithm for EN 1991-1-4:2005 Wind Loads

3.19.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the EN 1991-1-4:2005 are based on Section 5.3 of EN 1991-1-4:2005.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the peak velocity pressure, $q_p(z)$, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$q_p(z) = \tfrac{1}{2}\rho\left[1 + 7I_v(z)\right]\left[c_r(z)c_o(z)v_b\right]^2 \qquad \text{(EN 1991-1-4 Eqn. 4.8)}$$

where,

v_b = Basic wind speed in m/sec as input by the user

ρ = The air density. The values for ρ may be given in the National Annex. The programs use 1.25 kg/m^3 for this item.

$I_v(z)$ = The turbulent intensity at height z

$c_r(z)$ = The roughness factor

$c_o(z)$ = The orography factor as input by the user

The terrain roughness factor, $c_r(z)$, is obtained using (Eqns. 4.4 and 4.5 in EN 1991-1-4:2005 Section 4.3.2).

$$c_r(z) = k_r \ln\left(\frac{z}{z_o}\right) \text{ for } z_{min} \leq z \leq z_{max}$$

where,

$$k_r = 0.19\left(\frac{z_0}{z_{0,II}}\right)^{0.07}$$

$$c_r(z) = c_r(z)_{min} \leq z_{min} \qquad\qquad \text{(EN 1991-1-4 Eqn. 4.4 and 4.5)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered

z_0 = Roughness length as given in EN 1991-1-4 Table 4.1

$z_{0,II}$ = 0.05 m (terrain category II, EN 1991-1-4 Table 4.1)

z_{min} = Minimum height as defined in EN 1991-1-4 Table 4.1

z_{max} = is to be taken as 200 m

The turbulence intensity factor, $I_v(z)$, is obtained using (Eqns. 4.7 in EN 1991-1-4:2005 Section 4.4).

$$I_v(z) = \frac{k_I}{c_o(z)\ln(z/z_o)} \text{ for } z_{min} \leq z \leq z_{max}$$

$$I_v(z) = I_v(z_{min}) \text{ for } z \leq z_{min} \qquad\qquad \text{(EN 1991-1-4 Eqn. 4.7)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered.

k_I = Turbulence factor. The value of k_I may be given in the National Annex. The default value of k_I is 1.0

EN 1991-1-4:2005 Eqn. 5.1 and 5.5 are used to determine the wind pressure, w, at any point on the surface of the vertical projected area.

$$w = c_s c_d \, q_p(z) c_{p\text{-windward}} \; + \; c_s c_d \, q_p(z) c_{p\text{-leeward}} \quad \text{(EN 1991-1-4 Eqn. 5.1 and 5.5)}$$

where,

$q_p(z)$ = Velocity pressure, q_p, at any height z on the surface of the vertical projected area calculated using (EN 1991-1-4 Eqn. 4.8).

$c_s c_d$ = Structural factor as input by the user.

$c_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

$c_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The pressures, w, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, F_x and F_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis.

3.19.2.2 Exposure from Area Objects

Automatic wind loads for the EN 1991-1-4:2005 are based on Section 5.3 of EN 1991-1-4:2005.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects based on Section 5.3 of EN 1991-1-4:2005.

The following equation is used to determine the peak velocity pressure, $q_p(z)$, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$q_p(z) = \tfrac{1}{2}\rho\left[1 + 7I_v(z)\right]\left[c_r(z)c_o(z)v_b\right]^2 \qquad \text{(EN 1991-1-4 Eqn. 4.8)}$$

where,

v_b =   Basic wind speed in m/sec as input by the user

ρ =   The air density. The values for ρ may be given in the National Annex. The programs use 1.25 kg/m^3 for this item.

$I_v(z)$ =   The turbulent intensity at height z

$c_r(z)$ =   The roughness factor

$c_o(z)$ =   The orography factor as input by the user

The terrain roughness factor, $c_r(z)$, is obtained using (Eqns. 4.4 and 4.5 in EN 1991-1-4:2005 Section 4.3.2).

$$c_r(z) = k_r \ln\left(\frac{z}{z_o}\right) \text{ for } z_{\min} \leq z \leq z_{\max}$$

where,

$$k_r = 0.19\left(\frac{z_0}{z_{0,II}}\right)^{0.07}$$

$$c_r(z) = c_r(z)_{\min} \leq z_{\min} \qquad \text{(EN 1991-1-4 Eqn. 4.4 and 4.5)}$$

where,

z =   Distance (height) from input bottom story/minimum height to point considered.

z_0 =   Roughness length as given in EN 1991-1-4 Table 4.1

$z_{0,II}$ = 0.05 m (terrain category II, EN 1991-1-4 Table 4.1)

$z_{\min}$ = Minimum height as defined in EN 1991-1-4 Table 4.1

$z_{\max}$ = Is to be taken as 200 m.

The turbulence intensity factor, $I_v(z)$, is obtained using (Eqns. 4.7 in EN 1991-1-4:2005 Section 4.4).

$$I_v(z) = \frac{k_I}{c_o(z)\ln(z/z_o)} \text{ for } z_{min} \leq z \leq z_{max}$$

$$I_v(z) = I_v(z_{min}) \text{ for } z \leq z_{min} \qquad \text{(EN 1991-1-4 Eqn. 4.7)}$$

where,

z = Distance (height) from input bottom story/minimum height to point considered.

k_I = Turbulence factor. The value of k_I may be given in the National Annex. The default value of k_I is 1.0.

EN 1991-1-4:2005 Eqn. 5.1 and 5.5 are used to determine the wind pressure, w, at any point on the surface of the vertical projected area.

$$w = c_s c_d \, q_p(z) c_{p\text{-windward}} + c_s c_d \, q_p(z) c_{p\text{-leeward}}$$
$$\text{(EN 1991-1-4 Eqn. 5.1 and 5.5)}$$

where,

$q_p(z)$ = Velocity pressure, q_p, at any height z on the surface of the vertical projected area calculated using (EN 1991-1-4 Eqn. 4.8)

$c_s c_d$ = Structural factor as input by the user

$c_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

$c_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The programs distribute the pressures, w, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.20 2002 AS/NZS 1170.2 Wind Loads

3.20.1 Input Wind Coefficients

Eleven wind coefficients are input for AS/NZS 1170.2:2002 wind loads. They are the regional wind speed, V_R, in meter per second (m/sec), the wind direction multiplier, M_d, the terrain category, $M_{Z,cat}$, the shielding multiplier, M_s, the topographic multiplier, M_t, the identification of region (cyclonic/non-cyclonic), the dynamic response factor, C_{dyn} and four parameters $\left(K_{a,}\ K_c, K_l, K_p \right)$ that are used to compute aerodynamic shape factor, C_{fig}.

The regional wind speed, V_R, is described in AS/NZS 1170.2:2002 Section 3.2. For regions C and D, regional wind speed, V_R, includes additional factors $F_c = 1.05$ and $F_D = 1.1$ respectively.

The wind direction multiplier, M_d, is described in AS/NZS 1170.2:2002 Section 3.3. The programs are using $M_d = 1.0$ for all wind directions as default.

The terrain category, $M_{z,cat}$, is described in AS/NZS 1170.2:2002 Section 4.2. The terrain categories can be 1, 2, 3 and 4. The terrain category, $M_{Z,cat}$, accounts for the variability of the wind velocity at the site of the structure due to:

- the height of ground level

- the ground roughness of the terrain upwind of the structure in the wind direction considered

The shielding multiplier, M_s, is described in AS/NZS 1170.2:2002 Section 4.3.

The topographic multiplier, M_t, is described in AS/NZS 1170.2:2002 Section 4.4.

The aerodynamic shape factor, C_{fig}, is described in AS/NZS 1170.2:2002 Section 5.2.

The dynamic response factor, C_{dyn}, is described in AS/NZS 1170.2:2002 Section 6.1. For structures with a first mode fundamental frequency greater than 1Hz, $C_{dyn} = 1.0$. First mode fundamental frequencies between 0.2 Hz and 1Hz should be computed in accordance with AS/NZS 1170.2:2002 Section 6. Structures with a first mode that is less than 0.2 Hz are not covered by this Standard.

3.20.2 Algorithm for AS/NZS 1170.2:2002 Wind Loads

3.20.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the AS/NZS 1170.2:2002 are based on Section 2.4 of AS/NZS 1170.2:2002.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the design wind pressure, *p*, at any height *z* on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$p = \tfrac{1}{2}\rho_{air}\left[V_{des,\theta} \right]^2 C_{fig} C_{dyn} \qquad \text{(AS/NZS 1170.2 Eqn. 2.4(1))}$$

where,

$V_{des,\theta}$ = Building Orthogonal design wind speed in m/sec.

ρ_{air} = Air density. The values for ρ_{air} is taken as 1.2 kg/m^3.

C_{fig} = Aerodynamic shape factor.

C_{dyn} = Dynamic response factor as input by the user.

To simplify design, building orthogonal design wind speed is computed for the worst direction. Therefore, $V_{\text{des},\theta} = V_{\text{sit},\beta}$ in the program.

The site wind speed, $V_{\text{sit},\beta}$, at the reference height (z), above ground is computed as follows:

$$V_{\text{sit},\beta} = V_R M_d \left(M_{z,\text{cat}} M_s M_t \right) \geq 30 \quad \text{m/sec} \qquad \text{(AS/NZS 1170.2 Eqn. 2.2)}$$

where,

$V_{\text{sit},\beta}$ = Site wind speed in m/sec at the reference height (z) above ground

V_R = Regional 3 seconds gust wind speed in m/sec, for annual probability of exceedance of $1/R$, as input by the user.

M_d = Wind directional multiplier taken as 1.0 for all directions.

$M_{z,\text{cat}}$ = Terrain/height multiplier.

M_s = Shielding multiplier as input by the user.

M_t = Topographic multiplier as input by the user.

The terrain roughness on wind speed factor, $M_{z,\text{cat}}$, is obtained using AS/NZS 1170.2 Table 4.1(A) or Table 4.1(B).

The aerodynamic shape factor, C_{fig}, is obtained using Eqns. 5.2(1) in AS/NZS 1170.2:2002 Section 5.2.

$$C_{\text{fig}} = C_{p,e} K_a K_c K_l K_p \qquad \text{(AS/NZS 1170.2 Eqn. 5.2(1))}$$

where,

$C_{p,e}$ = external pressure coefficient as input by the user.

K_a = Area reduction factor. The value of K_a is given in AS/NZS 1170.2, Table 5.4. The default value of K_a is 1.0.

$K_c =$ Combination factor. The value of K_c is given in AS/NZS 1170.2, Table 5.5 and for all surfaces, K_c should not be less than $0.8/K_a$. The default value of K_c is 1.0.

$K_l =$ Local pressure factor. The value of K_l is given in AS/NZS 1170.2, Table 5.6. The local pressure factor K_l is 1.0 in all cases.

$K_p =$ Porous cladding reduction factor. The value of K_p is given in AS/NZS 1170.2, Table 5.8. The default value of K_p is 1.0.

AS/NZS 1170.2:2002 Eqn. 2.2, 2.4(1) and 5.2(1) are used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = \tfrac{1}{2}\rho_{\text{air}}\, C_{\text{dyn}} K_a K_c K_l K_p \left[\left(\left[V_{\text{des},\theta(z)} \right]^2 C_{p,e\text{-windward}} + \left[V_{\text{des},\theta(h)} \right]^2 C_{p,e\text{-leeward}} \right) \right]$$

where,

$c_{p,e\text{-windward}} =$ Windward external pressure coefficient as input by the user.

$c_{p,e\text{-leeward}} =$ Leeward external pressure coefficient as input by the user.

For leeward sides, wind speed is taken as the value at $z = h$. The $p(z), V_{\text{des},\theta(z)}$ varies with height, whereas $V_{\text{des},\theta(h)}$ remains constant.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, F_x and F_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis.

3.20.2.2 Exposure from Area Objects

Automatic wind loads for the AS/NZS 1170.2:2002 are based on Section 2.4 of AS/NZS 1170.2:2002.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects based on Section 2.4 of AS/NZS 1170.2:2002.

The following equation is used to determine the design wind pressure, p, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$p = \tfrac{1}{2}\rho_{air}\left[V_{des,\theta} \right]^2 C_{fig} C_{dyn} \qquad \text{(AS/NZS 1170.2 Eqn. 2.4(1))}$$

where,

$V_{des,\theta}$ =   Building Orthogonal design wind speed in m/sec.

ρ_{air} =   Air density. The values for ρ_{air} is taken as 1.2 kg/m^3.

C_{fig} =   Aerodynamic shape factor.

C_{dyn} =   Dynamic response factor as input by the user.

To simplify design, building orthogonal design wind speed is computed for the worst direction. Therefore, $V_{des,\theta} = V_{sit,\beta}$ in the program.

The site wind speed, $V_{sit,\beta}$, at the reference height (z), above ground is computed as follows:

$$V_{sit,\beta} = V_R M_d \left(M_{z,cat} M_s M_t \right) \ge 30 \text{ m/sec} \qquad \text{(AS/NZS 1170.2 Eqn. 2.2)}$$

where,

$V_{sit,\beta}$ =   Site wind speed in m/sec at the reference height (z) above ground

V_R = Regional 3 seconds gust wind speed in m/sec, for annual probability of exceedance of $1/R$, as input by the user.

M_d = Wind directional multiplier taken as 1.0 for all directions.

$M_{z,cat}$ = Terrain/height multiplier.

M_s = Shielding multiplier as input by the user.

M_t = Topographic multiplier as input by the user.

The terrain roughness on wind speed factor, $M_{z,\text{cat}}$, is obtained using AS/NZS 1170.2 Table 4.1(A) or Table 4.1(B).

The aerodynamic shape factor, C_{fig}, is obtained using Eqns. 5.2(1) in AS/NZS 1170.2:2002 Section 5.2.

$$C_{\text{fig}} = C_{p,e} K_a K_c K_l K_p \qquad \text{(AS/NZS 1170.2 Eqn. 5.2(1))}$$

where,

$C_{p,e} =$ external pressure coefficient as input by the user.

$K_a =$ Area reduction factor. The value of K_a is given in AS/NZS 1170.2, Table 5.4. The default value of K_a is 1.0.

$K_c =$ Combination factor. The value of K_c is given in AS/NZS 1170.2, Table 5.5 and for all surfaces, K_c should not be less than $0.8/K_a$. The default value of K_c is 1.0.

$K_l =$ Local pressure factor. The value of K_l is given in AS/NZS 1170.2, Table 5.6. The local pressure factor K_l is 1.0 in all cases.

$K_p =$ Porous cladding reduction factor. The value of K_p is given in AS/NZS 1170.2, Table 5.8. The default value of K_p is 1.0.

AS/NZS 1170.2:2002 Eqn. 2.2, 2.4(1) and 5.2(1) are used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = \tfrac{1}{2} \rho_{\text{air}} \left[V_{\text{des},\theta} \right]^2 C_{\text{dyn}} \left[\left(C_{p,e\text{-windward}} + C_{p,e\text{-leeward}} \right) K_a K_c K_l K_p \right]$$

where,

$c_{p,e\text{-windward}} =$ Windward external pressure coefficient as input by the user.

$c_{p,e\text{-leeward}} =$ Leeward external pressure coefficient as input by the user.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.21   2011 AS/NZS 1170.2 Wind Loads

3.21.1 Input Wind Coefficients

Eleven wind coefficients are input for AS/NZS 1170.2:2011 wind loads. They are the regional wind speed, V_R, in meter per second (m/sec), the wind direction multiplier, M_d, the terrain category, $M_{Z,cat}$, the shielding multiplier, M_s, the topographic multiplier, M_t, the identification of region (cyclonic/non-cyclonic), the dynamic response factor, C_{dyn} and four parameters $\left(K_a, \; K_c, K_l, K_p\right)$ that are used to compute aerodynamic shape factor, C_{fig}.

The regional wind speed, V_R, is described in AS/NZS 1170.2:2011 Section 3.2. For regions C and D, regional wind speed, V_R, includes additional factors $F_c = 1.05$ and $F_D = 1.1$ respectively.

The wind direction multiplier, M_d, is described in AS/NZS 1170.2:2011 Section 3.3. The programs are using $M_d = 1.0$ for all wind directions as default.

The terrain category, $M_{z,cat}$, is described in AS/NZS 1170.2:2011 Section 4.2. The terrain categories can be 1, 2, 3 and 4. The terrain category, $M_{Z,cat}$, accounts for the variability of the wind velocity at the site of the structure due to:

- the height of ground level

- the ground roughness of the terrain upwind of the structure in the wind direction considered

The shielding multiplier, M_s, is described in AS/NZS 1170.2:2011 Section 4.3.

The topographic multiplier, M_t, is described in AS/NZS 1170.2:2011 Section 4.4.

The aerodynamic shape factor, C_{fig}, is described in AS/NZS 1170.2:2011 Section 5.2.

The dynamic response factor, C_{dyn}, is described in AS/NZS 1170.2:2011 Section 6.1. For structures with a first mode fundamental frequency greater than 1Hz, $C_{dyn} = 1.0$. First mode fundamental frequencies between 0.2 Hz and 1Hz should be computed in accordance with AS/NZS 1170.2:2011 Section 6. Structures with a first mode that is less than 0.2 Hz are not covered by this Standard.

3.21.2 Algorithm for AS/NZS 1170.2:2011 Wind Loads

3.21.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the AS/NZS 1170.2:2011 are based on Section 2.4 of AS/NZS 1170.2:2011.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

Buildings with height over 70 m, a torsion force is also required based on the eccentricity of 0.2b with respect to the center of geometry of each diaphragm. Program provides an option for activating additional torsional moment for any building height in positive and negative directions. User must include torsional moments when building height is greater than 70m.

The following equation is used to determine the design wind pressure, p, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$p = \tfrac{1}{2}\rho_{air}\left[V_{des,\theta} \right]^2 C_{fig} C_{dyn} \qquad \text{(AS/NZS 1170.2 Eqn. 2.4(1))}$$

where,

$V_{des,\theta}$ = Building Orthogonal design wind speed in m/sec.

ρ_{air} = Air density. The values for ρ_{air} is taken as 1.2 kg/m^3.

C_{fig} = Aerodynamic shape factor as input by the user.

C_{dyn} = Dynamic response factor as input by the user.

To simplify design, building orthogonal design wind speed is computed for the worst direction. Therefore, $V_{\text{des},\theta} = V_{\text{sit},\beta}$ in the program.

The site wind speed, $V_{\text{sit},\beta}$, at the reference height (z), above ground is computed as follows:

$$V_{\text{sit},\beta} = V_R M_d \left(M_{z,\text{cat}} M_s M_t \right) \geq 30 \quad \text{m/sec} \qquad \text{(AS/NZS 1170.2 Eqn. 2.2)}$$

where,

$V_{\text{sit},\beta}$ = Site wind speed in m/sec at the reference height (z) above ground

V_R = Regional gust wind speed in m/sec, for annual probability of exceedance of $1/R$, as input by the user.

M_d = Wind directional multiplier taken as 1.0 for all directions.

$M_{z,\text{cat}}$ = Terrain/height multiplier.

M_s = Shielding multiplier as input by the user.

M_t = Topographic multiplier as input by the user.

The terrain roughness on wind speed factor, $M_{z,\text{cat}}$, is obtained using AS/NZS 1170.2 Table 4.1.

The aerodynamic shape factor, C_{fig}, is obtained using Eqns. 5.2(1) in AS/NZS 1170.2:2011 Section 5.2.

$$C_{\text{fig}} = C_{p,e} K_a K_c K_l K_p \qquad \text{(AS/NZS 1170.2 Eqn. 5.2(1))}$$

where,

$C_{p,e}$ = external pressure coefficient as input by the user.

K_a = Area reduction factor. The value of K_a is given in AS/NZS 1170.2, Table 5.4. The default value of K_a is 1.0.

K_c = Combination factor. The value of K_c is given in AS/NZS 1170.2, Table 5.5 and for all surfaces, K_c should not be less than $0.8/K_a$. The default value of K_c is 1.0.

K_l = Local pressure factor. The value of K_l is given in AS/NZS 1170.2, Table 5.6. The local pressure factor K_l is 1.0 in all cases.

K_p = Porous cladding reduction factor. The value of K_p is given in AS/NZS 1170.2, Table 5.8. The default value of K_p is 1.0.

AS/NZS 1170.2:2011 Eqn. 2.2, 2.4(1) and 5.2(1) are used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = \tfrac{1}{2}\rho_{air}\, C_{dyn}\, K_a K_c K_l K_p \left[\left(\left[V_{des,\theta(z)} \right]^2 C_{p,e\text{-windward}} + \left[V_{des,\theta(h)} \right]^2 C_{p,e\text{-leeward}} \right) \right]$$

where,

$c_{p,e\text{-windward}}$ = Windward external pressure coefficient as input by the user.

$c_{p,e\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

For leeward sides, wind speed is taken as the value at $z = h$. The $p(z), V_{des,\theta(z)}$ varies with height, whereas $V_{des,\theta(h)}$ remains constant.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, F_x and F_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis.

3.21.2.2 Exposure from Area Objects

Automatic wind loads for the AS/NZS 1170.2:2011 are based on Section 2.4 of AS/NZS 1170.2:2011.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects based on Section 2.4 of AS/NZS 1170.2:2011.

The following equation is used to determine the design wind pressure, p, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$p = \tfrac{1}{2}\rho_{air}\left[V_{des,\theta}\right]^2 C_{fig} C_{dyn} \qquad \text{(AS/NZS 1170.2 Eqn. 2.4(1))}$$

where,

$V_{des,\theta}$ = Building Orthogonal design wind speed in m/sec.

ρ_{air} = Air density. The values for ρ_{air} is taken as 1.2 kg/m^3.

C_{fig} = Aerodynamic shape factor.

C_{dyn} = Dynamic response factor as input by the user.

To simplify design, building orthogonal design wind speed is computed for the worst direction. Therefore, $V_{des,\theta} = V_{sit,\beta}$ in the program.

The site wind speed, $V_{sit,\beta}$, at the reference height (z), above ground is computed as follows:

$$V_{sit,\beta} = V_R M_d \left(M_{z,cat} M_s M_t\right) \geq 30 \text{ m/sec} \qquad \text{(AS/NZS 1170.2 Eqn. 2.2)}$$

where,

$V_{sit,\beta}$ = Site wind speed in m/sec at the reference height (z) above ground

V_R = Regional gust wind speed in m/sec, for annual probability of exceedance of $1/R$, as input by the user.

M_d = Wind directional multiplier taken as 1.0 for all directions.

$M_{z,\text{cat}}$ = Terrain/height multiplier.

M_s = Shielding multiplier as input by the user.

M_t = Topographic multiplier as input by the user.

The terrain roughness on wind speed factor, $M_{z,\text{cat}}$, is obtained using AS/NZS 1170.2 Table 4.1.

The aerodynamic shape factor, C_{fig}, is obtained using Eqns. 5.2(1) in AS/NZS 1170.2:2002 Section 5.2.

$$C_{\text{fig}} = C_{p,e} K_a K_c K_l K_p \qquad \text{(AS/NZS 1170.2 Eqn. 5.2(1))}$$

where,

$C_{p,e}$ = external pressure coefficient as input by the user.

K_a = Area reduction factor. The value of K_a is given in AS/NZS 1170.2, Table 5.4. The default value of K_a is 1.0.

K_c = Combination factor. The value of K_c is given in AS/NZS 1170.2, Table 5.5 and for all surfaces, K_c should not be less than $0.8/K_a$. The default value of K_c is 1.0.

K_l = Local pressure factor. The value of K_l is given in AS/NZS 1170.2, Table 5.6. The local pressure factor K_l is 1.0 in all cases.

K_p = Porous cladding reduction factor. The value of K_p is given in AS/NZS 1170.2, Table 5.8. The default value of K_p is 1.0.

AS/NZS 1170.2:2011 Eqn. 2.2, 2.4(1) and 5.2(1) are used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = \tfrac{1}{2}\rho_{\text{air}} \left[V_{\text{des},\theta} \right]^2 C_{\text{dyn}} \left[\left(C_{p,e\text{-windward}} + C_{p,e\text{-leeward}} \right) K_a K_c K_l K_p \right]$$

where,

$c_{p,e\text{-windward}} =$ Windward external pressure coefficient as input by the user.

$c_{p,e\text{-leeward}} =$ Leeward external pressure coefficient as input by the user.

The programs distribute the pressures, *p*, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.22 1987 Indian IS:875 Part-3 Wind Loads

3.22.1 Input Wind Coefficients

Five wind coefficients are input for IS:875 Indian wind loads. They are the basic wind speed V_b in meter per second (m/s), the terrain category, the structure class, Probability coefficient or Risk coefficient (k_1 *factor*) and topography factor (k_3 *factor*). Terrain, height, and structure size factor (k_2 *factor*) are evaluated by the program automatically from the terrain category and structure class specified by the user.

The basic wind speed is described in section 5.2 of IS:875 code. A typical range of values for the basic wind speed is 33 to 55 m/sec.

The terrain categories are described in section 5.3.2.1 of IS:875 code. The terrain category can be 1, 2, 3 or 4. No other values are allowed.

The structure classes are described in section 5.3.2.1 of IS:875 code. The structure class can be A, B or C. No other values are allowed.

3.22.2 Exposure from Extents of Diaphragms

Automatic wind loads for the IS:875 Indian code are based on section 6 of IS:875.

The wind load estimation when using the exposure from extents of diaphragms method is based on IS:875 section 6. The user must have defined diaphragms in the building model to use this method for wind load computation. Windward and leeward horizontal wind loads are applied on the vertical projected area of

the building as determined from the story heights and the input diaphragm exposure widths. The program does not apply vertical wind load automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the load pattern, the user must include them manually.

If a parapet exists at terrace level, the user can specify the parapet height and the resulting wind load due to exposure of the parapet wall to wind will be included automatically. Such a parapet is assumed to be located at the highest floor level along the boundary of the diaphragm. There may be certain situations when a lift machine room or a water tank could be modeled above the terrace level. In such a case, the highest floor level will be the floor level with maximum Z coordinate, which could be the roof of the lift machine room or the top slab of the water tank. Suppose the parapet exists at the terrace level; in that case, the program would not be able to identify the location of the parapet wall to correctly account for the wind load acting on the wall. Such a parapet wall height should not be specified on the form used to define the wind load. Wind loads acting on such parapets must be included by manually computing them, and such a wind load should be applied by the user at the appropriate location manually.

The following equation is used to determine the design wind pressure p_d, at any point on the surface of the vertical projected area.

$$p_d = 0.6V_z^2 \qquad \text{(IS:875 Section 5.4)}$$

where,

p_d = Design wind pressure

V_z = Design wind speed in m/sec

V_z = $V_b.k_1.k_2.k_3$

Other terms have already been explained.

The wind force on a vertical projected area is computed by the following equation.

$$F = C_p.A.p_d$$

where,

A = Vertical projected area

C_p = Net wind pressure coefficient for the windward or leeward surface

Note: The program does not compute the net wind pressure coefficients. The user should input net wind pressure coefficients on the windward and the leeward sides by considering all possibilities of external and internal pressures existing together or separately and specify them on the form used to define the wind load pattern. The following equation may be used to determine the coefficient C_p.

C_p = $C_{pe} - C_{pi}$

C_{pe} = External wind pressure coefficient

C_{pi} = Internal wind pressure coefficient

3.22.3 Exposure from Area Objects

Automatic wind loads for the IS:875 Indian code are based on section 6 of IS:875.

The wind load estimation when using the exposure from area objects method is based on IS:875 section 6. The user must have defined area objects in a vertical plane covering the building's outer surfaces exposed to wind to use this method of wind load computation. If no such vertical structural elements are present in the prototype building, the user can add dummy area objects with NULL property for the purpose of estimating wind loads acting on outer surfaces of the building. Typically the user will be applying windward and leeward wind coefficients to such vertical area objects. Windward and leeward horizontal wind loads are then computed and applied on the vertical area object, which in turn creates loads on the joints connected to the area objects. The program does not apply vertical wind load automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the load pattern, the user must include them manually.

The wind load acting on parapet walls existing above roof level can't be computed automatically when wind loads are estimated using exposure from area objects method. Assigning the parapet wall height in wind load definition dia-

log box will have no effect on wind load in this method. Wind load acting on parapets must be included by manually computing the wind load on them and such a wind load should be applied by the user at appropriate location manually.

The following equation is used to determine the design wind pressure p_d, at any point on the surface of the vertical projected area.

$$p_d = 0.6V_z^2 \hspace{3cm} \text{(IS:875 Section 5.4)}$$

where,

p_d = Design wind pressure

V_z = Design wind speed in m/sec.

$V_z = V_b.k_1.k_2.k_3$

Other terms have been explained already.

The wind force on a vertical projected area is computed by the following equation.

$$F = C_p.A.p_d$$

where,

A = Vertical projected area of area object, including dummy area

C_p = Net wind pressure coefficient for windward or leeward surfaces

Note: The program does not compute net wind pressure coefficients and the user should input net wind pressure coefficient on windward and leeward sides by considering all possibilities of external and internal pressures existing together or separately and specify it in the form used to define the wind load pattern. The following equation may be used to determine the coefficient C_p.

$$C_p = C_{pe} - C_{pi}$$

where,

C_{pe} = External wind pressure coefficient

C_{pi}= Internal wind pressure coefficient

Such a wind load coefficient, C_p, must be applied to the area object, including dummy area objects drawn by the user in elevation, identifying whether it is a windward or leeward coefficient.

3.23   2008 Italian NTC Wind Loads

3.23.1 Input Wind Coefficients

Six wind coefficients are input for Italian NTC 2008 wind loads. They are the basic wind speed, V_b, in meter per second (m/sec), the exposure category, the topography factor, c_t, Dynamic coefficient, c_d, and the shape factor, c_p.

The exposure category is described in NTC table 3.3.II. The exposure category can be I, II, III, IV and V. The topography factor, c_t, accounts for the variability of the mean wind velocity at the site of the structure due to:

- the height of the ground level

- the ground roughness of the terrain upwind from the structure in the wind direction considered

The Dynamic coefficient represents the interaction between the wind action and the dynamic response of the structure. For common structures it can be cautionary and taken as 1; for particular structures, it must be determined on the basis of specific analysis

The shape factor depends on the morphological properties of the structure. Values for the shape factor (also known as pressure coefficient) are reported in EC1 part 4 section 7. These values can be used also for the determination of the shape factor in accordance with NTC 2008.

3.23.2 Algorithm for Italian NTC 2008 Wind Loads

3.23.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for the Italian NTC 2008 are based on Section 3.3 of Italian NTC 2008.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To include those vertical wind loads in the same load pattern, the user must include them manually.

The following equation is used to determine the peak velocity pressure, $q_p(z)$, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$q_b = \frac{1}{2}\rho V_b^2 \qquad \text{(NTC 2008 Eqn. 3.3.4)}$$

where,

$\quad V_b \quad = \quad$ Basic wind speed in m/sec as input by the user

$\quad \rho \quad = \quad$ The air density. The programs use 1.25 kg/m^3 for this item.

The exposure coefficient is obtained using (Eqns. 3.3.5 in NTC 2008).

$$c_e(z) = \begin{cases} k_r^2 c_t ln\left(\dfrac{z}{z_0}\right)\left[7 + c_t ln\left(\dfrac{z}{z_0}\right)\right] & \text{for } z \geq z_{min} \\[2em] c_e(z_{min}) & \text{for } z < z_{min} \end{cases} \qquad \text{(NTC Eqn. 3.3.5)}$$

where,

z is the height of the considered point from the base of the structure

k_r, z_0, z_{min} depend on the exposure category of the site as defined in NTC 2008 table 3.3.II

Exposure Category	k_r	Z_0 [m]	Z_{min} [m]
I	0.17	0.01	2
II	0.19	0.05	4
III	0.20	0.10	5

IV	0.22	0.30	8
V	0.23	0.70	12

c_t is the "topography" factor which can be, in general, set equal to 1

EN 1991-1-4:2005 Eqn. 5.1 and 5.5 are used to determine the wind pressure, w, at any point on the surface of the vertical projected area.

$$w = c_e c_d \, q_b c_{\text{p-windward}} \; + \; c_e c_d \, q_b c_{\text{p-leeward}} \qquad \text{(NTC 2008 Eqn. 3.3.2)}$$

where,

q_b = Velocity pressure, q_b, at any height z on the surface of the vertical projected area calculated using (NTC 2008 Eqn. 3.3.4).

c_e = Exposure coefficient

c_p = Shape factor or pressure coefficient

c_d = Dynamic coefficient

q_b = Dynamic pressure

$c_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

$c_{\text{p-leeward}}$ = Leeward external pressure coefficient as input by the user.

The pressures, w, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis as shown in Figure 3-1. The application of these pressures determines a resultant lateral force in both the x- and y-directions of the building, F_x and F_y, at each diaphragm level. Note that one or the other of these forces may be zero if the wind direction is perfectly aligned with the x- or y-axis.

3.23.2.2 Exposure from Area Objects

Automatic wind loads for the NTC 2008 are based on Section 3.3 of NTC 2008.

The wind loads applied when using the exposure from area objects method are applied on the vertical and horizontal surfaces of the user selected area objects are based on Section 3.3 of Italian NTC 2008.

The following equation is used to determine the peak velocity pressure, q_b, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$q_b = \frac{1}{2}\rho\, V_b^{\,2} \qquad\qquad \text{(NTC 2008 Eqn. 3.3.4)}$$

where,

V_b = Basic wind speed in m/sec as input by the user

ρ = The air density. The programs use 1.25 kg/m^3 for this item.

The exposure coefficient is obtained using (Eqns. 3.3.5 in NTC 2008).

$$c_e(z) = \begin{cases} k_r^2 c_t ln\left(\dfrac{z}{z_0}\right)\left[7 + c_t ln\left(\dfrac{z}{z_0}\right)\right] & \text{for } z \geq z_{\min} \\[1.5em] c_e(z_{\min}) & \text{for } z < z_{\min} \end{cases} \qquad \text{(NTC Eqn. 3.3.5)}$$

where,

z is the height of the considered point from the base of the structure

k_r, z_0, $z_{\min}$, depend on the exposure category of the site as defined in NTC 2008 table 3.3.II

Exposure Category	k_r	z_0 [m]	$z_{\min}$ [m]
I	0.17	0.01	2
II	0.19	0.05	4
III	0.20	0.10	5
IV	0.22	0.30	8
V	0.23	0.70	12

c_t is the "topography" factor which can be, in general, set equal to 1

EN 1991-1-4:2005 Eqn. 5.1 and 5.5 are used to determine the wind pressure, w, at any point on the surface of the vertical projected area.

$$w = c_e c_d\, q_b c_{p\text{-windward}} \; + \; c_e c_d\, q_b c_{p\text{-leeward}} \qquad \text{(NTC 2008 Eqn. 3.3.2)}$$

where,

q_b = Velocity pressure, q_b, at any height z on the surface of the vertical projected area calculated using (NTC 2008 Eqn. 3.3.4).

c_e = Exposure coefficient

c_p = Shape factor pressure coefficient

c_d = Dynamic coefficient

q_b = Dynamic pressure

$c_{p\text{-windward}}$ = Windward external pressure coefficient as input by the user.

$c_{p\text{-leeward}}$ = Leeward external pressure coefficient as input by the user.

The programs distribute the pressures, w, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.24   1997 TS 498 Wind Loads

3.24.1 Input Wind Coefficients

Two wind coefficients are input for 1997 TS 498 wind loads. They are the wind speed, V, in m/sec and the coefficient of dynamic, C_r.

The velocity pressure, q, can be obtained from 1997 TS 498 from section 11.3.

The coefficient of dynamic, C_r, is discussed in 1997 TS 498 section 11.2.2. The default value is 1.0. Any positive value is allowed.

3.24.2 Algorithm for 1997 TS 498 Wind Loads

3.24.2.1 Exposure from Extents of Diaphragms

Automatic wind loads for 1997 TS 498 are based on Section 11.2 of the 1997 TS 498.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To

include those vertical wind loads in the load pattern, the user must include them manually.

The following equation is used to determine the peak velocity pressure, q, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$q = \frac{V^2}{1600}$$

(TS 498 Section 11.3)

where,

V = Basic wind speed in m/sec as input by the user

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = q\ C_r\ [C_{p\text{-windward}} + C_{p\text{-leeward}}]$$

(TS 498 Section11.2.3)

where,

q = Velocity pressure.

C_r = Dynamic factor as input by the user.

$C_{p\text{-windward}}$ = External pressure coefficient for the windward wall as input by the user.

$C_{p\text{-leeward}}$ = External pressure coefficient for the leeward wall as input by the user.

The pressures, p, are distributed on the surface of the vertical projected area to each diaphragm on a tributary area basis, as shown in Figure 3-1.

3.24.2.2 Exposure from Area Objects

Automatic wind loads for 1997 TS 498 are based on Section 11.2 of the 1997 TS 498.

Windward and leeward horizontal wind loads are applied on the vertical projected area of the building as determined from the story heights and the input diaphragm exposure widths. The programs do not apply vertical wind loads automatically over the projected horizontal area of roof surfaces. To

include those vertical wind loads in the load pattern, the user must include them manually.

The following equation is used to determine the peak velocity pressure, q, at any height z on the surface of the vertical projected area, in Newton per square meter (N/m^2).

$$q = \frac{\rho V^2}{2g} \qquad \text{(TS 498 Section 11.3)}$$

where,

$\quad V_b \quad = \quad$ Basic wind speed in m/sec as input by the user

$\quad \rho \quad = \quad$ The air density. The programs use 1.25 kg/m^3 for this item.

The following equation is used to determine the wind pressure, p, at any point on the surface of the vertical projected area.

$$p = q\, C_r\, [C_{p\text{-winward}} + C_{p\text{-leeward}}] \qquad \text{(TS 498 Section11.2.3)}$$

where,

$\quad q \quad = \quad$ Velocity pressure.

$\quad C_r \quad = \quad$ Dynamic factor as input by the user.

$\quad C_{p\text{-windward}} = \quad$ External pressure coefficient for the windward wall as input by the user.

$\quad C_{p\text{-leeward}} \quad = \quad$ External pressure coefficient for the leeward wall as input by the user.

The programs distribute the pressures, p, on the surface of each area object, which in turn creates loads on the joints connected to the area objects.

3.25 User-Defined Wind Loads

For user-defined loads, define the magnitude of the wind load force in the X- and Y-directions, the torsional moment, and the location of the wind load force

to each diaphragm at each story level. On the basis of these data, a point object is automatically created at the location of the applied load.

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