PDHonline Course S232 (2 PDH)

Seismic Analysis Values with Spreadsheet

Instructor: John W. Andrew, PE

2012

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone & Fax: 703-988-0088
www.PDHonline.org
www.PDHcenter.com

Seismic Analysis Values with Spreadsheet

John W. Andrew, PE

INTRODUCTION

The seismic response coefficient, $C_{s,}$ is used to determine the design seismic base shear using the equivalent lateral force procedure in accordance with the provisions of Section 12.8. The design base shear is the product of the seismic design coefficient, C_s, and the effective seismic weight of the structure, W.

The SDC classification is important in the seismic design of a building. If a building is classified as category A, then the building may be designed in accordance with Section 11.7 only. Each subsequent letter classification (B through F) results in an increase in seismic design requirements. This includes permissible structural systems, height limits, permissible analysis procedures, detailing requirements and requirements for nonstructural components.

The earthquake provisions of ASCE 7-05 chapters 11-13 and 15-23 are based on the 2003 NEHRP Provisions. Calculation of the seismic design coefficient, C_S, is based on the spectral response accelerations, seismic importance factor, fundamental period of the building, long-period transition period and response modification factor. These factors are determined using the occupancy category, site class and building period coefficients.

OCCUPANCY CATEGORY

The occupancy category is determined by the classifications described in Table 1-1. Category I is assigned to buildings that represent a low hazard to human life in the event of failure. Category II is assigned to most buildings - it is assigned to buildings not otherwise classified as category I, III or IV. Category III is assigned to buildings with large numbers of people, such as buildings where more than 300 people congregate in one area, schools with more than 250 students, buildings with an occupant load exceeding 5,000, nonessential utility facilities and jails and detention facilities. Category IV is assigned to essential facilities, such as hospitals, fire stations, police stations, aviation control towers, buildings containing highly toxic materials and public utility facilities required in an emergency.

SEISMIC IMPORTANCE FACTOR

The seismic importance factor (I) is a modification of the seismic base shear to reflect the relative importance assigned to the building occupancy during and following an earthquake. The importance factor is determined using Table 11.5-1. For buildings assigned to Occupancy Category I or II, I = 1.0. For buildings assigned to Occupancy Category III, I=1.25. For buildings assigned to Occupancy Category IV, I = 1.5.

RESPONSE MODIFICATION FACTOR

The response modification coefficient (R) represents the ability of the structure to resist the design seismic loading without failure. It also represents the reduction in the design seismic loading resulting from the perceived relative ductility of the structural system. The response modification coefficient is determined using Table 12.2-1.

SITE CLASS

The soil at the building site must be classified as Site Class A, B, C, D, E or F in accordance with the definitions in Table 20.3-1. When the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used, unless the building official determines that Site Class E or F soil is present at the site.

SPECTRAL RESPONSE ACCELERATIONS AND SITE COEFFICIENTS

The mapped maximum considered earthquake (MCE) spectral response accelerations at short periods (S_s) and at 1-second period (S_1) can be determined from Figures 22-1 through 22-14. The acceleration-based site coefficient at 0.3 second period (F_a) can be determined from Table 11.4-1. The acceleration-based site coefficient at 1.0 second period (F_v) can be determined from Table 11.4-2. The values for S_s, S_1, F_a and F_v are also available on the USGS website at http://earthquake.usgs.gov/research/hazmaps/design.

On the home page of the USGS web site, click on Java Ground Motion Parameter Calculator . In the File Download Dialog Box, click on “Open” to download the software. Click on “Okay”. Click on “Lat/Lon” tab to enter building location using latitude and longitude or “Zip Code” to enter building location using the postal zip code. After entering the latitude and longitude or the zip code, click on “Calculate Ss & S_1”. The values for S_s and S_1 for Site Class B will be displayed. Click on “Calculate S_M & S_D Values”. On the Set Site Class pull down menu, select the site class for the building location and click “OK”. The values for F_a and F_v will be displayed, as well as the values for S_{MS}, S_{M1}, S_{DS} and S_{D1}. The output may be printed by clicking on “Print” on the “File” pull down menu.

BUILDING PERIOD COEFFICIENTS

The building period coefficients C_t and x vary with the structure type and are determined from Table 12.8-2. h_n is the height in feet above the base to the highest level of the building.

SPECTRAL RESPONSE ACCELERATIONS ADJUSTED FOR SITE CLASS EFFECTS

S_{MS} is the maximum considered earthquake, 5% damped, spectral response acceleration at short periods adjusted for site class effects as defined in Section 11.4.3.

$S_{MS} = F_a S_s$.

S_{M1} is the maximum considered earthquake, 5% damped, spectral response acceleration at a period of 1-sec adjusted for site class effects as defined in Section 11.4.3.

$S_{M1} = F_v S_1$.

S_{DS} is the design, 5% damped, spectral response acceleration at short periods as defined in Section 11.4.4.

$S_{DS} = (2/3) S_{MS}$

S_{D1} is the design, 5% damped, spectral response acceleration at a period of 1 sec as defined in Section 9.4.1.2.

$S_{D1} = (2/3) S_{M1}$

FUNDAMENTAL PERIOD OF BUILDING

T_a is the approximate fundamental period of the building as determined by Section 12.8.2.1.

$T_a = C_t (h_n)^x$.

SEISMIC RESPONSE COEFFICIENT

C_s is the seismic response coefficient for the building as determined by Section 12.8.1.1.

$C_s = \dfrac{S_{DS} I}{R}$ except that the seismic design coefficient need not be greater than

$\dfrac{S_{D1} I}{R T}$ for $T <= T_L$ or

$\dfrac{S_{D1} T_L I}{R T^2}$ for $T > T_L$ and

shall not be less than 0.01 or

less than $\dfrac{(.5) S_1 I}{R}$ if $S_1 >= 60$ %g.

where T_L is the long-period transition period as shown in Figures 22-15 through 22-20.

SEISMIC DESIGN CATEGORY

The seismic design category (SDC) is determined by Table 11.6-1 and Table 11.6-2. Based on the values of S_{DS} and S_{D1} and the Occupancy Caregory, the seismic design category is assigned as the more severe SDC as determined by the two tables. However, an exception allows only Table 11.6-1 to be used if the provisions stated in Paragraph 11.6 apply.

EXAMPLE PROBLEM

Determine the seismic design coefficient, C_S, and the seismic design category (SDC) for a one-story health care facility with a capacity of 60 resident patients, but without surgery or emergency treatment facilities, to be built in Atlanta, Georgia. The roof structure will be wood trusses. The supporting walls will be wood studs. The lateral force resisting system will be a light-framed wall system using flat strap bracing. The height of the structure will be 18 feet. The soil at the project site has been classified as site class D. The latitude at the building site is 33.9 degrees and the longitude is –84.3 degrees. The approximate fundamental period of the structure is less than $0.8T_S$, the fundamental period of the structure used to calculate the story drift is less than T_s and the diaphragm is rigid.

From Table 1-1, the occupancy classification was is category III. From Table 11.5-1, for Occupancy Category III, the seismic importance factor, I, is 1.25.

From Table 12.2-1, the response modification factor,

$R = 4$

From the USGS web site, the spectral response accelerations and acceleration-based site coefficients are as follows:

$S_s = 23.9$ %g

$S_1 = 8.8$ %g

$F_a = 1.60$

$F_v = 2.40$

From Table 12.8-2, for structure type “all other structural systems”, the building period coefficients are as follows:

$C_t = 0.02$

$x = 0.75$

The height to the highest level of the building,

$h_n = 18$ feet.

From Figure 22-15,

T_L = 12 sec

$S_{MS} = F_a\ S_S$

S_{MS} = (1.60) (.239) = .382

$S_{M1} = F_v\ S_1$

S_{M1} = (2.40) (.088) = .211

S_{DS} = (2/3) S_{MS}

S_{DS} = (2/3) (.382) = .255

S_{D1} = (2/3) S_{M1}

S_{D1} = (2/3) (.211) = .141

$C_S = S_{DS}$ I / R

C_S = (.255) (1.25) / 4 = .080

$T = C_T\ (h_n)^{0.75}$

$T = (.02)\ (18.00)^{0.75}$ = .175 sec

For T <= T_L , C_S need not exceed (.141) (1.25) / 4 / .175 = .252

C_S shall not be less than .010

C_S = .080

The example problem above is entered in the spreadsheet. The Excel © spreadsheet has the appropriate formulas embedded and provides references to applicable references for entries required. The formulas and calculated results are in protected cells so that they may not be inadvertently changed. Information provided by the user is entered into yellow unprotected cells. Calculation results are provided in blue colored cells. With the data entered in the appropriate cells, the seismic design coefficient, **C_s = 0.080**. Because Equation 12.8-2 was used to determine C_s and the approximate fundamental period of the structure is less than $0.8T_S$, the fundamental period of the structure used to calculate the story drift is less than T_s and the diaphragm is rigid, Table 11.6-1 only may be used to determine the seismic design category. For a value of S_{DS} equal to 0.255 in Occupancy Category III, the building is assigned to **Seismic Design Category B.**

REFERENCES

1. Minimum Design Loads for Buildings and Other Structures (ASCE Standard ASCE/SEI 7-05), American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191.

2. 2006 IBC Handbook Structural Provisions, International Code Council, 4051 Flossmoor Rd., Country Club Hills, IL 60478.