



Nuclear Regulatory Commission
 Exhibit # - NRC034-00-BD01
 Docket # - 07007016
 Identified : 7/11/2012

Admitted: 7/11/2012
 Rejected:

Withdrawn:
 Stricken:

STRUCTURAL DESIGN

Section 1613, Earthquake Loads
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NRC034

identified by the building official and that are the minimum necessary to assure safe living conditions.

2. Any alteration of a historic structure provided that the alteration will not preclude the structure's continued designation as a historic structure.

1612.3 Establishment of flood hazard areas. To establish flood hazard areas, the governing body shall adopt a flood hazard map and supporting data. The flood hazard map shall include, at a minimum, areas of special flood hazard as identified by the Federal Emergency Management Agency in an engineering report entitled "The Flood Insurance Study for [INSERT NAME OF JURISDICTION]," dated [INSERT DATE OF ISSUANCE], as amended or revised with the accompanying Flood Insurance Rate Map (FIRM) and Flood Boundary and Floodway Map (FBFM) and related supporting data along with any revisions thereto. The adopted flood hazard map and supporting data are hereby adopted by reference and declared to be part of this section.

1612.4 Design and construction. The design and construction of buildings and structures located in flood hazard areas, including flood hazard areas subject to high velocity wave action, shall be in accordance with ASCE 24.

1612.5 Flood hazard documentation. The following documentation shall be prepared and sealed by a registered design professional and submitted to the building official:

1. For construction in flood hazard areas not subject to high-velocity wave action:
 - 1.1. The elevation of the lowest floor, including the basement, as required by the lowest floor elevation inspection in Section 109.3.3.
 - 1.2. For fully enclosed areas below the design flood elevation where provisions to allow for the automatic entry and exit of floodwaters do not meet the minimum requirements in Section 2.6.2.1 of ASCE 24, construction documents shall include a statement that the design will provide for equalization of hydrostatic flood forces in accordance with Section 2.6.2.2 of ASCE 24.
 - 1.3. For dry floodproofed nonresidential buildings, construction documents shall include a statement that the dry floodproofing is designed in accordance with ASCE 24.
2. For construction in flood hazard areas subject to high-velocity wave action:
 - 2.1. The elevation of the bottom of the lowest horizontal structural member as required by the lowest floor elevation inspection in Section 109.3.3.
 - 2.2. Construction documents shall include a statement that the building is designed in accordance with ASCE 24, including that the pile or column foundation and building or structure to be attached thereto is designed to be anchored to resist flotation, collapse and lateral movement due to the effects of wind and flood loads acting simultaneously on all building components, and other load requirements of Chapter 16.

- 2.3. For breakaway walls designed to resist a nominal load of less than 10 psf (0.48 kN/m²) or more than 20 psf (0.96 kN/m²), construction documents shall include a statement that the breakaway wall is designed in accordance with ASCE 24.

SECTION 1613 EARTHQUAKE LOADS

1613.1 Scope. Every structure, and portion thereof, including nonstructural components that are permanently attached to structures and their supports and attachments, shall be designed and constructed to resist the effects of earthquake motions in accordance with ASCE 7, excluding Chapter 14 and Appendix 11A. The seismic design category for a structure is permitted to be determined in accordance with Section 1613 or ASCE 7.

Exceptions:

1. Detached one- and two-family dwellings, assigned to Seismic Design Category A, B or C, or located where the mapped short-period spectral response acceleration, S_s , is less than 0.4 g.
2. The seismic-force-resisting system of wood-frame buildings that conform to the provisions of Section 2308 are not required to be analyzed as specified in this section.
3. Agricultural storage structures intended only for incidental human occupancy.
4. Structures that require special consideration of their response characteristics and environment that are not addressed by this code or ASCE 7 and for which other regulations provide seismic criteria, such as vehicular bridges, electrical transmission towers, hydraulic structures, buried utility lines and their appurtenances and nuclear reactors.

1613.2 Definitions. The following words and terms shall, for the purposes of this section, have the meanings shown herein.

DESIGN EARTHQUAKE GROUND MOTION. The earthquake ground motion that buildings and structures are specifically proportioned to resist in Section 1613.

MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION. The most severe earthquake effects considered by this code.

MECHANICAL SYSTEMS. For the purposes of determining seismic loads in ASCE 7, mechanical systems shall include plumbing systems as specified therein.

ORTHOGONAL. To be in two horizontal directions, at 90 degrees (1.57 rad) to each other.

SEISMIC DESIGN CATEGORY. A classification assigned to a structure based on its occupancy category and the severity of the design earthquake ground motion at the site.

SEISMIC-FORCE-RESISTING SYSTEM. That part of the structural system that has been considered in the design to provide the required resistance to the prescribed seismic forces.

SITE CLASS. A classification assigned to a site based on the types of soils present and their engineering properties as defined in Section 1613.5.2.

SITE COEFFICIENTS. The values of F_a and F_v indicated in Tables 1613.5.3(1) and 1613.5.3(2), respectively.

1613.3 Existing buildings. Additions, alterations, modification, or change of occupancy of existing buildings shall be in accordance with Sections 3403.2.3 and 3406.4.

1613.4 Special inspections. Where required by Section 1705.3, the statement of special inspections shall include the special inspections required by Section 1705.3.1.

1613.5 Seismic ground motion values. Seismic ground motion values shall be determined in accordance with this section.

1613.5.1 Mapped acceleration parameters. The parameters S_s and S_1 shall be determined from the 0.2 and 1-second spectral response accelerations shown on Figures 1613.5(1) through 1613.5(14). Where S_1 is less than or equal to 0.04 and S_s is less than or equal to 0.15, the structure is permitted to be assigned to Seismic Design Category A.

1613.5.2 Site class definitions. Based on the site soil properties, the site shall be classified as either Site Class A, B, C,

D, E or F in accordance with Table 1613.5.2. When the site soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the building official or geotechnical data determines that Site Class E or F soil is likely to be present at the site.

1613.5.3 Site coefficients and adjusted maximum considered earthquake spectral response acceleration parameters. The maximum considered earthquake spectral response acceleration for short periods, S_{MS} , and at 1-second period, S_{M1} , adjusted for site class effects shall be determined by Equations 16-37 and 16-38, respectively:

$$S_{MS} = F_a S_s \quad (\text{Equation 16-37})$$

$$S_{M1} = F_v S_1 \quad (\text{Equation 16-38})$$

where:

F_a = Site coefficient defined in Table 1613.5.3(1).

F_v = Site coefficient defined in Table 1613.5.3(2).

S_s = The mapped spectral accelerations for short periods as determined in Section 1613.5.1.

S_1 = The mapped spectral accelerations for a 1-second period as determined in Section 1613.5.1.

TABLE 1613.5.2
 SITE CLASS DEFINITIONS

| SITE CLASS | SOIL PROFILE NAME | AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5 | | |
|------------|-------------------------------|---|--|--|
| | | Soil shear wave velocity, \bar{v}_s , (ft/s) | Standard penetration resistance, \bar{N} | Soil undrained shear strength, \bar{s}_u , (psf) |
| A | Hard rock | $\bar{v}_s > 5,000$ | N/A | N/A |
| B | Rock | $2,500 < \bar{v}_s \leq 5,000$ | N/A | N/A |
| C | Very dense soil and soft rock | $1,200 < \bar{v}_s \leq 2,500$ | $\bar{N} > 50$ | $\bar{s}_u \geq 2,000$ |
| D | Stiff soil profile | $600 \leq \bar{v}_s \leq 1,200$ | $15 \leq \bar{N} \leq 50$ | $1,000 \leq \bar{s}_u \leq 2,000$ |
| E | Soft soil profile | $\bar{v}_s < 600$ | $\bar{N} < 15$ | $\bar{s}_u < 1,000$ |
| E | — | Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf | | |
| F | — | Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet) | | |

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

TABLE 1613.5.3(1)
 VALUES OF SITE COEFFICIENT F_a ^a

| SITE CLASS | MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIOD | | | | |
|------------|---|--------------|--------------|--------------|-----------------|
| | $S_s \leq 0.25$ | $S_s = 0.50$ | $S_s = 0.75$ | $S_s = 1.00$ | $S_s \geq 1.25$ |
| A | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| C | 1.2 | 1.2 | 1.1 | 1.0 | 1.0 |
| D | 1.6 | 1.4 | 1.2 | 1.1 | 1.0 |
| E | 2.5 | 1.7 | 1.2 | 0.9 | 0.9 |
| F | Note b | Note b | Note b | Note b | Note b |

- a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period, S_s .
 b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

TABLE 1613.5.3(2)
 VALUES OF SITE COEFFICIENT F_v ^a

| SITE CLASS | MAPPED SPECTRAL RESPONSE ACCELERATION AT 1-SECOND PERIOD | | | | |
|------------|--|-------------|-------------|-------------|----------------|
| | $S_1 \leq 0.1$ | $S_1 = 0.2$ | $S_1 = 0.3$ | $S_1 = 0.4$ | $S_1 \geq 0.5$ |
| A | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| C | 1.7 | 1.6 | 1.5 | 1.4 | 1.3 |
| D | 2.4 | 2.0 | 1.8 | 1.6 | 1.5 |
| E | 3.5 | 3.2 | 2.8 | 2.4 | 2.4 |
| F | Note b | Note b | Note b | Note b | Note b |

- a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at 1-second period, S_1 .
 b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

1613.5.4 Design spectral response acceleration parameters. Five-percent damped design spectral response acceleration at short periods, S_{DS} , and at 1-second period, S_{D1} , shall be determined from Equations 16-39 and 16-40, respectively:

$$S_{DS} = \frac{2}{3} S_{MS} \quad (\text{Equation 16-39})$$

$$S_{D1} = \frac{2}{3} S_{M1} \quad (\text{Equation 16-40})$$

where:

S_{MS} = The maximum considered earthquake spectral response accelerations for short period as determined in Section 1613.5.3.

S_{M1} = The maximum considered earthquake spectral response accelerations for 1-second period as determined in Section 1613.5.3.

1613.5.5 Site classification for seismic design. Site classification for Site Class C, D or E shall be determined from Table 1613.5.5.

The notations presented below apply to the upper 100 feet (30 480 mm) of the site profile. Profiles containing distinctly different soil and/or rock layers shall be subdivided into those layers designated by a number that ranges from 1 to n at the bottom where there is a total of n distinct layers in the upper 100 feet (30 480 mm). The symbol i then refers to any one of the layers between 1 and n .

where:

v_{si} = The shear wave velocity in feet per second (m/s).

d_i = The thickness of any layer between 0 and 100 feet (30 480 mm).

where:

$$\bar{v}_s = \frac{\sum_{i=1}^n d_i}{\sum_{i=1}^n \frac{d_i}{v_{si}}} \quad (\text{Equation 16-41})$$

$$\sum_{i=1}^n d_i = 100 \text{ feet (30 480 mm)}$$

N_i is the Standard Penetration Resistance (ASTM D 1586) not to exceed 100 blows/foot (305 mm) as directly measured in the field without corrections. When refusal is met for a rock layer, N_i shall be taken as 100 blows/foot (305 mm).

$$\bar{N} = \frac{\sum_{i=1}^n d_i}{\sum_{i=1}^n \frac{d_i}{N_i}} \quad (\text{Equation 16-42})$$

where N_i and d_i in Equation 16-42 are for cohesionless soil, cohesive soil and rock layers.

$$\bar{N}_{ch} = \frac{d_s}{\sum_{i=1}^m \frac{d_i}{N_i}} \quad (\text{Equation 16-43})$$

where:

$$\sum_{i=1}^m d_i = d_s$$

Use d_i and N_i for cohesionless soil layers only in Equation 16-43.

d_s = The total thickness of cohesionless soil layers in the top 100 feet (30 480 mm).

m = The number of cohesionless soil layers in the top 100 feet (30 480 mm).

s_{ui} = The undrained shear strength in psf (kPa), not to exceed 5,000 psf (240 kPa), ASTM D 2166 or D 2850.

$$\bar{s}_u = \frac{d_c}{\sum_{i=1}^k \frac{d_i}{s_{ui}}} \quad (\text{Equation 16-44})$$

where:

$$\sum_{i=1}^k d_i = d_c$$

d_c = The total thickness of cohesive soil layers in the top 100 feet (30 480 mm).

k = The number of cohesive soil layers in the top 100 feet (30 480 mm).

PI = The plasticity index, ASTM D 4318.

w = The moisture content in percent, ASTM D 2216.

Where a site does not qualify under the criteria for Site Class F and there is a total thickness of soft clay greater than 10 feet (3048 mm) where a soft clay layer is defined by: $s_u < 500$ psf (24 kPa), $w \geq 40$ percent, and $PI > 20$, it shall be classified as Site Class E.

The shear wave velocity for rock, Site Class B, shall be either measured on site or estimated by a geotechnical engineer or engineering geologist/seismologist for competent rock with moderate fracturing and weathering. Softer and more highly fractured and weathered rock shall either be measured on site for shear wave velocity or classified as Site Class C.

The hard rock category, Site Class A, shall be supported by shear wave velocity measurements either on site or on profiles of the same rock type in the same formation with an equal or greater degree of weathering and fracturing. Where hard rock conditions are known to be continuous to a depth of 100 feet (30 480 mm), surficial shear wave velocity measurements are permitted to be extrapolated to assess v_s .

The rock categories, Site Classes A and B, shall not be used if there is more than 10 feet (3048 mm) of soil between the rock surface and the bottom of the spread footing or mat foundation.

1613.5.5.1 Steps for classifying a site.

1. Check for the four categories of Site Class F requiring site-specific evaluation. If the site corresponds to any of these categories, classify the site as Site Class F and conduct a site-specific evaluation.
2. Check for the existence of a total thickness of soft clay > 10 feet (3048 mm) where a soft clay layer is defined by: $s_u < 500$ psf (24 kPa), $w \geq 40$ percent and $PI > 20$. If these criteria are satisfied, classify the site as Site Class E.
3. Categorize the site using one of the following three methods with v_s , \bar{N} , and \bar{s}_u and computed in all cases as specified.

TABLE 1613.5.5
 SITE CLASSIFICATION^a

| SITE CLASS | v_s | \bar{N} or \bar{N}_{ch} | \bar{s}_u |
|------------|---------------------|-----------------------------|--------------------|
| E | < 600 ft/s | < 15 | < 1,000 psf |
| D | 600 to 1,200 ft/s | 15 to 50 | 1,000 to 2,000 psf |
| C | 1,200 to 2,500 ft/s | > 50 | > 2,000 |

For SI: 1 foot per second = 304.8 mm per second, 1 pound per square foot = 0.0479 kN/m².

a. If the \bar{s}_u method is used and the \bar{N}_{ch} and \bar{s}_u criteria differ, select the category with the softer soils (for example, use Site Class E instead of D).

- 3.1. \bar{v}_s for the top 100 feet (30 480 mm) (\bar{v}_s method).
- 3.2. \bar{N}_{ch} for the top 100 feet (30 480 mm) (\bar{N} method).
- 3.3. \bar{N} for cohesionless soil layers ($PI < 20$) in the top 100 feet (30 480 mm) and average, s_u for cohesive soil layers ($PI > 20$) in the top 100 feet (30 480 mm) (s_u method).

1613.5.6 Determination of seismic design category. Occupancy Category I, II or III structures located where the mapped spectral response acceleration parameter at 1-second period, S_1 , is greater than or equal to 0.75 shall be assigned to Seismic Design Category E. Occupancy Category IV structures located where the mapped spectral response acceleration parameter at 1-second period, S_1 , is greater than or equal to 0.75 shall be assigned to Seismic Design Category F. All other structures shall be assigned to a seismic design category based on their occupancy category and the design spectral response acceleration coefficients, S_{DS} and S_{D1} , determined in accordance with Section 1613.5.4 or the site-specific procedures of ASCE 7. Each building and structure shall be assigned to the more severe seismic design category in accordance with Table 1613.5.6(1) or 1613.5.6(2), irrespective of the fundamental period of vibration of the structure, T .

TABLE 1613.5.6(1)
SEISMIC DESIGN CATEGORY BASED ON
SHORT-PERIOD RESPONSE ACCELERATIONS

| VALUE OF S_{DS} | OCCUPANCY CATEGORY | | |
|------------------------------|--------------------|-----|----|
| | I or II | III | IV |
| $S_{DS} < 0.167g$ | A | A | A |
| $0.167g \leq S_{DS} < 0.33g$ | B | B | C |
| $0.33g \leq S_{DS} < 0.50g$ | C | C | D |
| $0.50g \leq S_{DS}$ | D | D | D |

TABLE 1613.5.6(2)
SEISMIC DESIGN CATEGORY BASED ON
1-SECOND PERIOD RESPONSE ACCELERATION

| VALUE OF S_{D1} | OCCUPANCY CATEGORY | | |
|-------------------------------|--------------------|-----|----|
| | I or II | III | IV |
| $S_{D1} < 0.067g$ | A | A | A |
| $0.067g \leq S_{D1} < 0.133g$ | B | B | C |
| $0.133g \leq S_{D1} < 0.20g$ | C | C | D |
| $0.20g \leq S_{D1}$ | D | D | D |

1613.5.6.1 Alternative seismic design category determination. Where S_1 is less than 0.75, the seismic design category is permitted to be determined from Table 1613.5.6(1) alone when all of the following apply:

- In each of the two orthogonal directions, the approximate fundamental period of the structure, T_a , in each of the two orthogonal directions determined in accordance with Section 12.8.2.1 of ASCE 7, is less than $0.8 T_s$ determined in accordance with Section 11.4.5 of ASCE 7.
- In each of the two orthogonal directions, the fundamental period of the structure used to calculate the story drift is less than T_s .
- Equation 12.8-2 of ASCE 7 is used to determine the seismic response coefficient, C_s .
- The diaphragms are rigid as defined in Section 12.3.1 in ASCE 7 or for diaphragms that are flexible, the distance between vertical elements of the seismic-force-resisting system does not exceed 40 feet (12 192 mm).

1613.5.6.2 Simplified design procedure. Where the alternate simplified design procedure of ASCE 7 is used, the seismic design category shall be determined in accordance with ASCE 7.

1613.6 Alternatives to ASCE 7. The provisions of Section 1613.6 shall be permitted as alternatives to the relevant provisions of ASCE 7.

1613.6.1 Assumption of flexible diaphragm. Add the following text at the end of Section 12.3.1.1 of ASCE 7:

Diaphragms constructed of wood structural panels or untopped steel decking shall also be permitted to be idealized as flexible, provided all of the following conditions are met:

- Toppings of concrete or similar materials are not placed over wood structural panel diaphragms except for nonstructural toppings no greater than $1\frac{1}{2}$ inches (38 mm) thick.
- Each line of vertical elements of the lateral-force-resisting system complies with the allowable story drift of Table 12.12-1.
- Vertical elements of the lateral-force-resisting system are light-framed walls sheathed with wood structural panels rated for shear resistance or steel sheets.
- Portions of wood structural panel diaphragms that cantilever beyond the vertical elements of the lateral-force-resisting system are designed in accordance with Section 2305.2.5 of the *International Building Code*.

1613.6.2 Additional seismic-force-resisting systems for seismically isolated structures. Add the following exception to the end of Section 17.5.4.2 of ASCE 7:

Exception: For isolated structures designed in accordance with this standard, the Structural System Limitations and the Building Height Limitations in Table 12.2-1 for ordinary steel concentrically braced frames (OCBFs) as defined in Chapter 11 and ordinary moment frames (OMFs) as defined in Chapter 11 are permitted to be taken as 160 feet (48 768 mm) for structures assigned to Seismic Design Category D, E or F, provided that the following conditions are satisfied:

1. The value of R_t as defined in Chapter 17 is taken as 1.
2. For OMFs and OCBFs, design is in accordance with AISC 341.

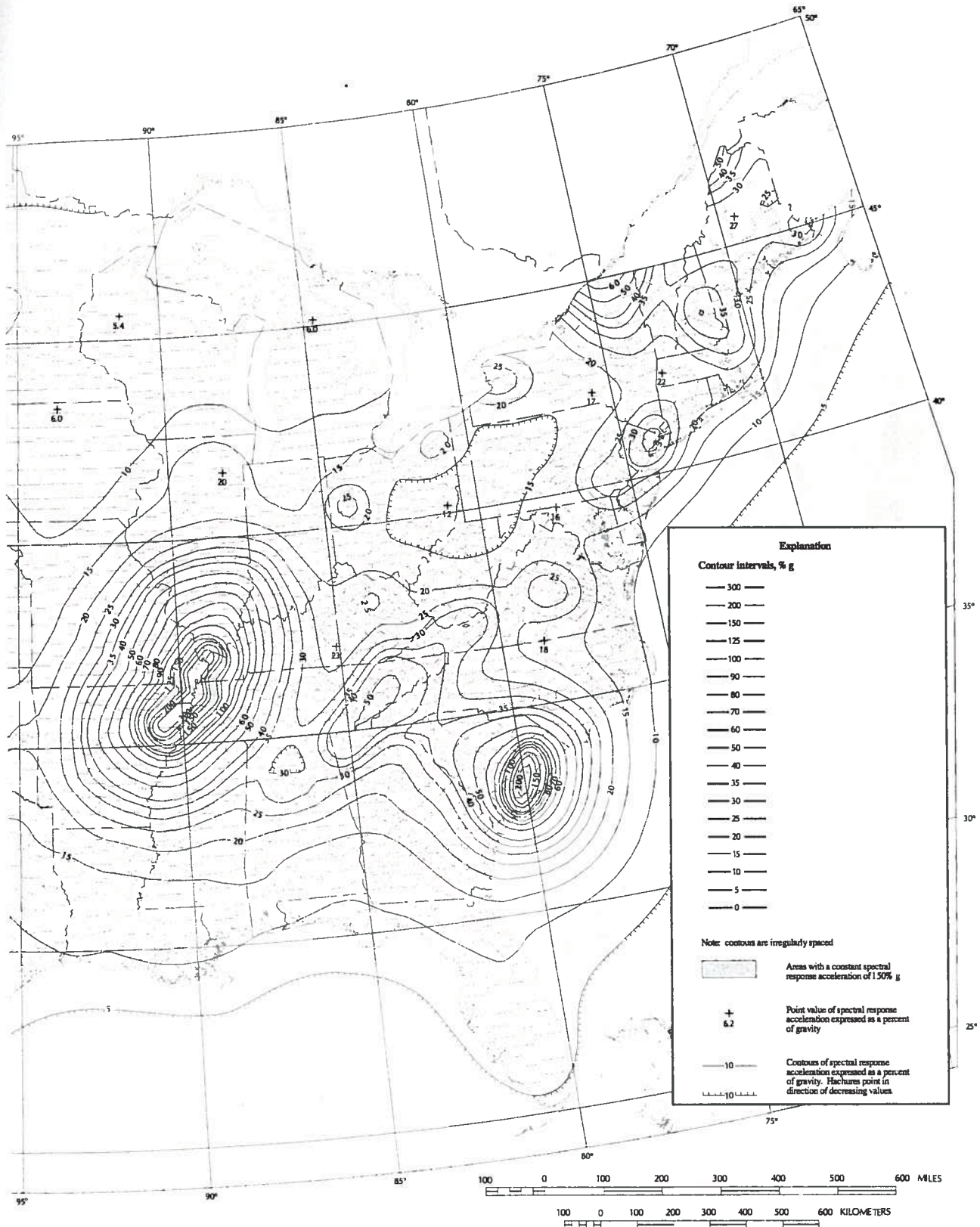


FIGURE 1613.5(1)—continued
 MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION FOR THE CONTERMINOUS UNITED STATES OF
 0.2 SEC SPECTRAL RESPONSE ACCELERATION (5% OF CRITICAL DAMPING), SITE CLASS B

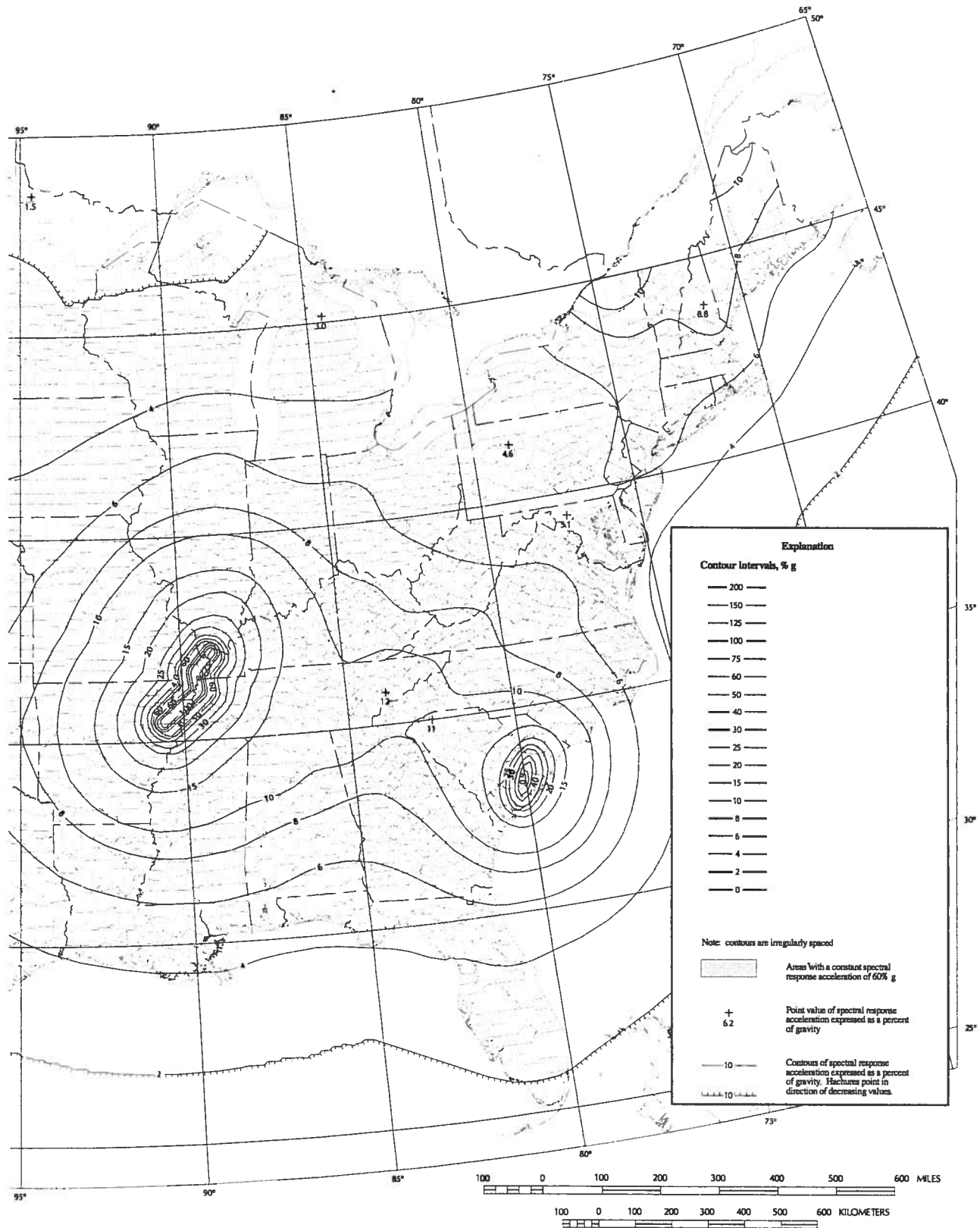


FIGURE 1613.5(2)—continued
 MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION FOR THE CONTERMINOUS UNITED STATES
 OF 1.0 SEC SPECTRAL RESPONSE ACCELERATION (5% OF CRITICAL DAMPING), SITE CLASS B

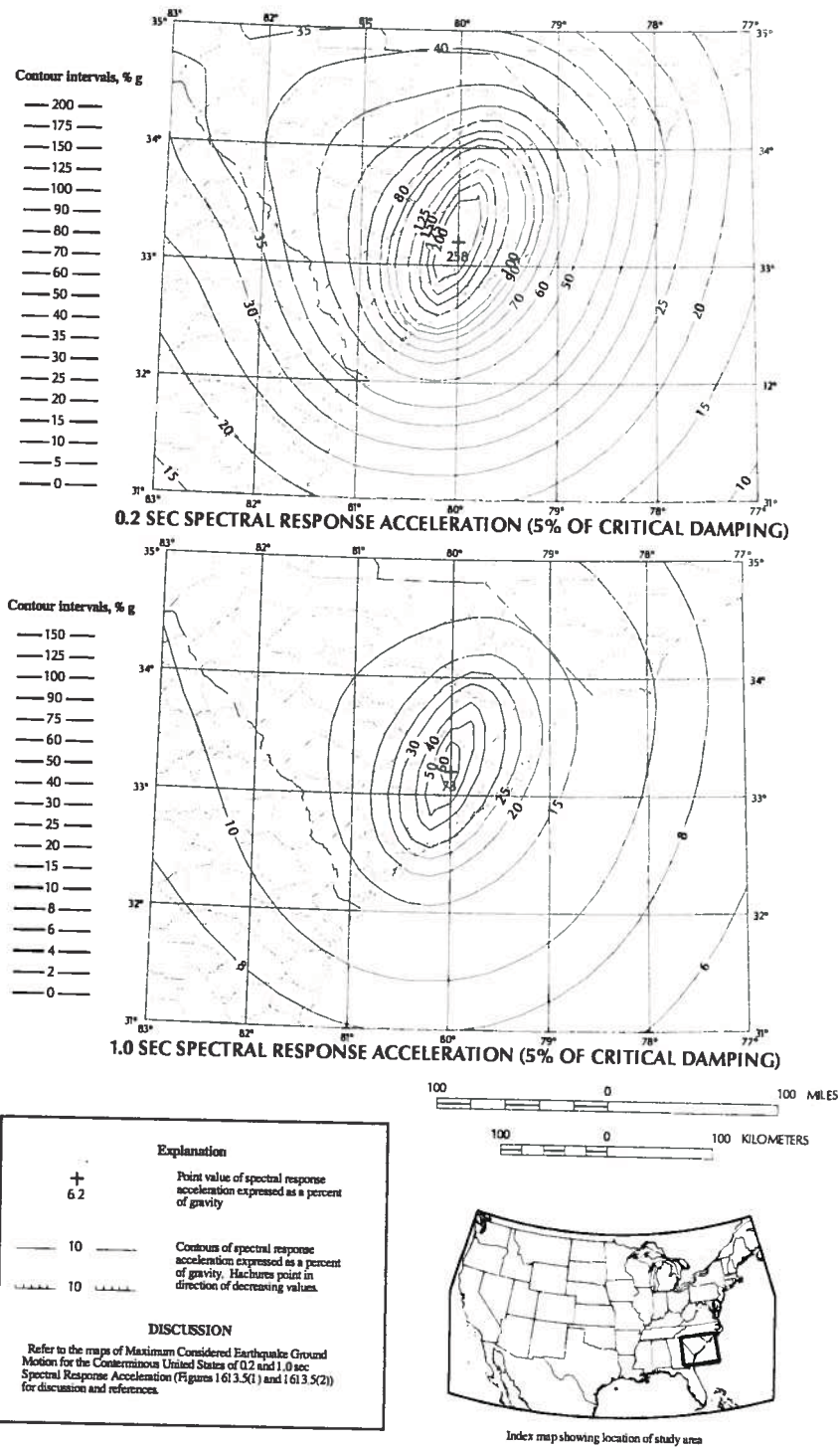


FIGURE 1613.5(9)
MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION FOR REGION 4 OF
0.2 AND 1.0 SEC SPECTRAL RESPONSE ACCELERATION (5% OF CRITICAL DAMPING), SITE CLASS B