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Minimum Recommended SSC Laboratory Seismic Design Requirements

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MINIMUM RECOMMENDED

SSC LABORATORY SEISMIC DESIGN REQUIREMENTS

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ABSTRACT

The Superconducting Super Collider (SSC) Laboratory has been strategically located in Ellis County, Texas where design, construction, operation, and maintenance costs would be minimized. One of the parameters that affect costs during these phases of the Laboratory life-cycle is the geological stability of the area with respect to seismic ground motion. Historical records demonstrate that bedrock accelerations expected to occur at any one time during the 20-year operating life of the facility for the project site will generate forces on both surface and sub-surface structures of a magnitude less than the minimum forces required by current governing engineering design codes. The Uniform Building Code designates the SSC site to lie within Seismic Zone 0, but remains silent with regard to minimum lateral loading for the zone. The specific magnitudes of the minimum applied forces are therefore to be determined from an application of both ASCE 7-88 (formerly ANSI A58.1) and FEMA 222, referenced by Department of Energy DOE 6430.1A (*General Design Criteria*), the governing design code for the SSC. The conclusion of the seismic study has resulted in a recommendation for minimum seismic lateral forces on all structures of the SSC, which is to be included in the SSC Laboratory Facility Design Criteria.

ACKNOWLEDGEMENTS

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INTRODUCTION

The Superconducting Super Collider (SSC) Laboratory has been strategically located in Ellis County, Texas where design, construction, operation, and maintenance costs would be minimized. One of the parameters that affects costs during the design and construction phases of the laboratory life-cycle is the geological stability of the area with respect to seismic ground motion. Historical records demonstrate that bedrock accelerations expected to occur at any one time during the 20- year operating life of the facility for the project site will generate forces on both surface and subsurface structures of a magnitude less than the minimum forces required by current governing engineering design codes. Specifically, the Uniform Building Code locates the site within the Seismic Zone 0, but remains silent with respect to a Zone 0 minimum lateral loading. The specific magnitude of the minimum applied forces must therefore be determined from an application of both ASCE 7-88 *Minimum Design Loads for Buildings and Other Structures* (formerly ANSI A58.1) and FEMA 222, *Federal Emergency Management Administration*, referenced by and in compliance with DOE 6430.1A, the governing design code for the SSC.

The Seismic Design Requirements Working Group was formed for the purpose of studying the requirements that were set forth in various site governing codes referenced by DOE 6430.1A, while considering actual motion history to derive a single governing set of seismic design criteria for all structures of the SSC. The purpose of the study was to generate a lab-wide standard criteria for design of all structures of the SSC with dual perspectives of providing the required safety by preventing under design while minimizing costs by preventing over design. The recommendations of the Seismic Design Requirements Working Group are documented in this report and included in the SSC Laboratory Facility Design Criteria.

PURPOSE

The SSC Laboratory will consist of both surface and subsurface, highly complex and intricate technical experimental equipment. Lateral structural stability of such heavy, delicate equipment becomes an issue when no specific lateral loading requirements intrinsically exist. The purpose of this study was to develop minimum lateral loading requirements for the safest yet least costly design of all enclosed technical equipment as well as submerged conventional facilities, where surface wind does not govern.

SCOPE

The SSC Laboratory minimum lateral loading requirements stem from a sound engineering need to enforce lateral stability through application of a virtual seismic equivalent lateral acceleration. Since the actual seismic activity in a Zone 0 is viewed as being less than adequate for lateral stability, a larger virtual seismic equivalent is used as the minimum. The *General Design Criteria* of the Department of Energy (DOE 6430.1A), which governs the global design of all facilities of the SSC Laboratory, refers to the American Society of Civil Engineers publication ASCE 7-88, *Minimum Design Loads for Buildings and Other Structures* (formerly ANSI A58.1) and FEMA 222, *Federal Emergency Management Administration.* The design of all facilities and technical equipment of the SSC Laboratory shall be subject to this minimum lateral stability constraint unless it can be show that a higher lateral loading would govern.

SEISMICITY UNDER DOE 6430.1A GENERAL DESIGN CRITERIA

The Department of Energy (DOE) has published guidelines for the design of structures with respect to earthquake and other seismic activities. The DOE order 6430.1A, *United States Department of Energy General Design Criteria* states:

> "The basic seismic parameters shall be derived from DOE site-specific hazard model studies summarized in UCRL 53582. If site-specific hazard model studies are not available, a hazard model shall be developed that is consistent with the approach used in UCRL 53582. In

applying UCRL 53582, specific guidance on relating frequency of occurrence to facility hazard levels shall be obtained from UCRL 15910.

Earthquake load design for buildings and other structures shall be determined in accordance with the procedures contained in the UBC and UCRL 15910. The provisions and design procedures of TM 5-809-10 for the application of seismic loading to conventional buildings shall also apply. For critical facilities, the provisions and design procedures of TM 5-809-10.1 shall be used." [1]

Since the SSC Laboratory is located in the lowest seismic zone area (Zone 0), the procedures as outlined in the Uniform Building Code (UBC) will be used in lieu of University of California Research Laboratory (UCRL) 15910. UBC indicates that the SSC Laboratory is located within the Seismic Zone 0 in accordance with Figure 1. The table that corresponds to the UBC (Table 1) does not give a seismic zone coefficient for Zone 0. Since the UBC remains silent regarding seismicity for Zone 0, other codes such as American Society of Civil Engineers (ASCE 7-88), *Minimum Design Loads for Buildings and Other Structures* (formerly ANSI A58.1), and the Federal Emergency Management Administration, (FEMA 222 / 223) shall be applied to determine the minimum requirements for a specific Zone 0 design. The minimum requirements of ASCE 7-88 and FEMA 222 / 223 meet the seismic requirements of the procedure the Army Technical Manual (TM) 5-809-10.

Since the SSC Laboratory is not considered a critical facility, the requirements of the procedure TM 5-809-10.1 do not apply. The approach used by ASCE 7-88 and FEMA 222 / 223 is consistent with that depicted in UCRL 53582. Therefore ASCE 7-88 and FEMA 222 / 223 will govern for the SSC, since both of the references give a specific seismic zone coefficient for Zone 0.

SEISMICITY UNDER ASCE 7-88 (FORMERLY ANSI A58.1)

The seismic zone map (Figure 2) of ASCE 7-88 reflects a SSC Laboratory locale of Zone 0.[2] For structures in Seismic Zone 0, ASCE 7-88 requires that the minimum lateral seismic force be dissipated through the structural connections into the lateral resistive elements, i.e., floors, roofs, etc.[3]

Anchorage of Concrete and Masonry Walls

A positive direct connection between a laterally-supporting floor/roof and a concrete/masonry wall connected to it shall be capable of resisting a horizontal force (Fp) specified by the equation:

$$Fp = Z*I*Cp*Wp \qquad (1)$$

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[1] Office of Project and Facilites Management, *United States Department of Energy General Design Criteria,* (DOE 6430.1A), June 89, Section 0111-2.7.1, p 1-93.

[2] American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures (ASCE Standard 7-88),* July 1990, p 33.

[3] Ibid., pp 32, 40.

where Z represents the seismic zone numerical coefficient, shown in Table 2 with a value of 0.125 corresponding to Zone 0. All facilities of the SSC Laboratory reside within Zone 0 on the seismic zone map.

The Occupancy Importance Factor (I) is defined by Tables 3 and 4. Within the SSC Laboratory, some buildings will house more than 300 people, all of which fall under Category II, rendering an I value of 1.25. The remaining SSC buildings and structures fall within Category I, for which I = 1.0.

The Horizontal Force Factor for the structural elements of the SSC Laboratory facilities is defined to be 0.3. A Cp = 0.3 applies also to building connections for prefabricated structural elements other than walls with the forces effectively applied at the centers of gravity of the assemblies and resisted by positive anchorage forces, not frictional resistance.

The weight of the portion or part of the structure (Wp) includes the total dead and applicable live load for that section.

$$Fp = 0.125*1.25*0.3*Wp < 0.05*Wp,$$

so that Fp = 0.05*Wp will be taken as the minimum required horizontal force.

Load Paths

All parts of the building or structure that transmit seismic forces shall be connected through a continuous path to the resisting element. The connection and the elements along the path to the resisting element shall be capable of withstanding a minimum force (Fp), determined to be the greater force from the following equations (1) 0r (2):

$$Fp = 0.15*Z*I*Wp \qquad (2)$$

For Seismic Zone 0, Z = 0.125; for Category II occupancy, I =1.25. Thus

$$Fp = 0.15*0.125*1.25*Wp$$

$$Fp = 0.023*Wp$$

for equation (2), or

$$Fp = 0.05*Wp \qquad (1)$$

for equation (1).

Equation (1) is the more stringent requirement that will govern the SSC Laboratory structures. Therefore, the minimum horizontal force (Fp) shall be determined by:

$$Fp = 0.05*Wp$$

where Wp is the dead load and any applicable live load portion of the structure.

SEISMICITY UNDER FEMA 222

The requirements for the SSC Laboratory facilities imposed by FEMA 222 shall be considered the minimum loading requirements based upon an Effective Peak Acceleration (EPA) of less than 0.05g, as shown in the Figure 3 zone map. This EPA, according to FEMA 222, has a 0.1 probability of being exceeded in 50 years. (A probability of 0.9 that the EPA will not be exceeded during a 50 year period). Seismic Hazard Exposure Group I and an EPA = 0.05g categorizes SSC Laboratory facilities.[4] SSC Laboratory facilities fall into Group I because the facilities are not emergency stations nor public places as would be for groups II and III. With Group I classification and EPA of 0.05g, the Seismic Performance Category is A, corresponding to a zone of low earthquake risk where the building seismic design need only account for proper connections and anchorage of concrete or masonry walls.[5]

Anchorage of Concrete or Masonry Walls

Concrete or masonry walls shall be anchored to the roof and all floors that provide lateral support for the wall. The positive direct connection between the walls and the floors/roofs shall withstand the greater of the two seismic lateral forces:

$$Fp = 1000*Av \text{ (plf of the wall)} \qquad (5)$$

or

$$Fp = 0.05*Wp. \qquad (6)$$

A_V is the EPV acceleration in units of g, here 0.05. Wp is the live and dead load of the portion of the structure. Substituting we have

$$Fp = 1000*0.05$$

$$Fp = 50 \text{ pounds per linear foot of the wall}$$

or

$$Fp = 0.05*Wp.$$

The equation applicable to the SSC is the resulting combination of equation (5) and equation (6):

$$Fp = 0.05*Wp \text{ with a minimum of 50 pounds per linear foot.}$$

Connections (Load Paths)

All parts of a building between separation joints shall be interconnected. Connections shall be capable of transmitting (resisting) the greater of the following two seismic forces (Fp) induced by the parts being connected:

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[4] Federal Emergency Management Agency, *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings,* 1991 Edition, Part 1, pp 3-5

[5] Ibid., pp 45-6.

$$Fp = (A_V/3) * Wp \qquad (3)$$

or

$$Fp = 0.05*Wp. \qquad (4)$$

where A_V is the effective peak velocity-related acceleration corresponding to the effective peak velocity (EPV) in units of g, which is less than 0.05 from the contour map (Figure 4). The probability of exceeding this value is less than 10% for any 50-year period. Wp is the applicable live load and dead load of the **smaller** connected part.

Substituting we find the equation below that yields the greater value, which will govern the SSC facilities:

$$Fp = (0.05/3) * Wp$$

$$Fp = 0.017*Wp$$

or

$$Fp = 0.05*Wp.$$

By comparison the greater Fp results from equation (4). The SSC Laboratory shall use the following seismic force equation for design purposes:

$$Fp = 0.05*Wp$$

where Wp is the total live and dead load of the **smaller** connecting part.

Also note, in general, that a positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder, or truss to its support. The connection shall have a minimum strength so as to transmit (resist) a force Fp defined as follows:

$$Fp = 0.05*Rp$$

where Rp is the total dead and live load **reaction** of the beam, girder, or truss.[6]

SPECIAL STRUCTURES AND CONSIDERATIONS

The minimum requirements for the SSC Laboratory may not suffice for certain technical components. Special structures that contain large, concentrated masses, high aspect ratios, and unique support requirements, such as large detectors, may exhibit dynamic characteristics that fall outside of this static envelope and so may need to be subjected to additional and more comprehensive response spectrum or time history analysis.

Non-structural components that may be critical to SSC Laboratory operation, such as control units, high voltage electrical equipment, and cryogenic devices may experience secondary damages from seismic loadings due to overturning or failed supporting or anchoring mechanisms. These secondary or non-structural damage potentials may require additional seismic hazard loading considerations.

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[6]Ibid., p 46.

COMPARISON OF ASCE 7-88 (ANSI A58.1) AND FEMA 222

Both ASCE 7-88 and FEMA 222 / 223 impose the identical minimum lateral force criteria, with the additional constraint of member reaction minimums on connections mentioned in FEMA 222 noted above. The design requirements and the connection type constraints are identical. The information from the two standards is elementary and readily available. Both standards provide minimum requirement limitations. The strength of the structural connections must exceed the lateral force (Fp).

CONCLUSION

The equation from ANSI A58.1 gave the lateral force (Fp) to be no less than 0.05*Wp (Wp is the total live and dead load). FEMA 222 dictates the lateral force to be 0.05*Wp with a minimum of 50 lb. / ft. Both documents give the same requirements for the lateral force. The guidelines of both documents are in compliance with the UBC. In conclusion, both documents are used as standards for constructing the seismic requirements for the SSC.

RECOMMENDATIONS

WE RECOMMEND THAT ALL FACILITIES AND STRUCTURES, INCLUDING TECHNICAL SYSTEMS COMPONENTS, AT THE SSC LABORATORY BE DESIGNED TO WITHSTAND A MINIMUM LATERAL FORCE AS SPECIFIED IN ASCE 7-88. WE ALSO RECOMMEND THAT A SEISMIC DESIGN SECTION, THAT REFLECTS THE HEREIN CONTAINED MINIMUM CONSTRAINTS, BE INCORPORATED INTO THE SSC LABORATORY FACILITY DESIGN CRITERIA.

REFERENCES

1. American National Standard (American Society of Civil Engineers), "Minimum Design Loads for Buildings and other Structures ," ANSI A58.1 (ASCE 7-88). July, 1990.
2. Building Seismic Safety Council, "1991 Edition NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings, Part 1, Provisions," FEMA 222. January, 1992.
3. Building Safety Council, "1991 Edition NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings, Part 2, Commentary, "FEMA 223. January, 1992.
4. International Conference of Building Officials, "Uniform Building Code 1991 Edition," ISSN 0896-9655. May 1, 1991.
5. United States Department of Energy, "General Design Criteria," DOE 6430.1A. April 6,1989.

Seismic Zone Factor Z

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

Table 1

Table 1 gives the value of Factor Z for the Uniform Building Code seismic zones. As seen in the table, Zone 0 in which SSC Laboratory is located does not appear, so that UBC is silent with respect to the value of Z for the SSC Laboratory site.

Seismic Zone Coefficient, Z

Seismic Zone	Z
4	1
3	3/4
2	3/8
1	3/16
0	1/8

Table 2

Table 2 gives the value of Z for each seismic zone according to the location of the facility depicted in Figure 2. Table 2 and Figure 2 appear in ASCE 7-88 (ANSI A58.1).

Classification of Buildings and Other Structures for Wind, Snow, and Earthquake Loads

Nature of occupancy	Category
All buildings and structures except those listed below	I
Buildings and structures where the primary occupancy is one in which more than 300 people congregate in one area	II
Buildings and structures designated as essential facilities, including, but not limited to:	III
Hospital and other medical facilities having surgery or emergency treatment areas	
Fire or rescue and police stations	
Structures and equipment in government	
Communication centers and other facilities required for emergency response	
Power stations and other utilities required in an emergency	
Structures having critical national defense capabilities	
Designated shelters for hurricanes	
Buildings and structures that represent a low hazard to human life in the event of failure, such as agricultural buildings, certain temporary facilities, and minor storage facilities	IV

Table 3

Table 3 locates the SSC Laboratory in a category according to the occupancy of the building, which is given a numerical value in Table 4. All of the information is used to retrieve a value for *I* which is used in the equation from ASCE 7-88 (ANSI A58.1).

Occupancy Importance Factor, *I*
(Earthquake Loads)

Category	*I*
I	1.0
II	1.25
III	1.5
IV	NA

Table 4

Horizontal Force Factor, Cp for Elements of Structures and Non structural Components

Part or portion of building	Direction of horizontal force	Cp
Exterior bearing and nonbearing walls; interior bearing walls and partitions; interior nonbearing walls and partitions; masonry or concrete fences over 6 feet high	Normal to flat surface	0.3
Cantilever elements:		
Parapets	Normal to flat surface	0.8
Chimneys or tracks	Any direction	
Exterior and Interior ornamentation's and appendages	Any direction	0.8
When connected to part of or housed within a building:		
Penthouses, anchorage and supports for chimneys, stacks, and tanks, including contents		
Storage racks with upper storage level at more than 8 feet in height, plus contents	Any direction	0.3
All equipment or machinery		
Fire sprinkler system		
Suspended ceiling framing systems (applies to Seismic Zones 2, 3, and 4 only)	Any direction	0.3
Connections for prefabricated structural elements other than walls, with force applied at center of gravity or assembly	Any direction	0.3
Access floor systems	Any direction	0.3

Table 5

Table 5 renders the value for the horizontal force factor Cp, which is used in the equation from ASCE 7-88 (ANSI A58.1).

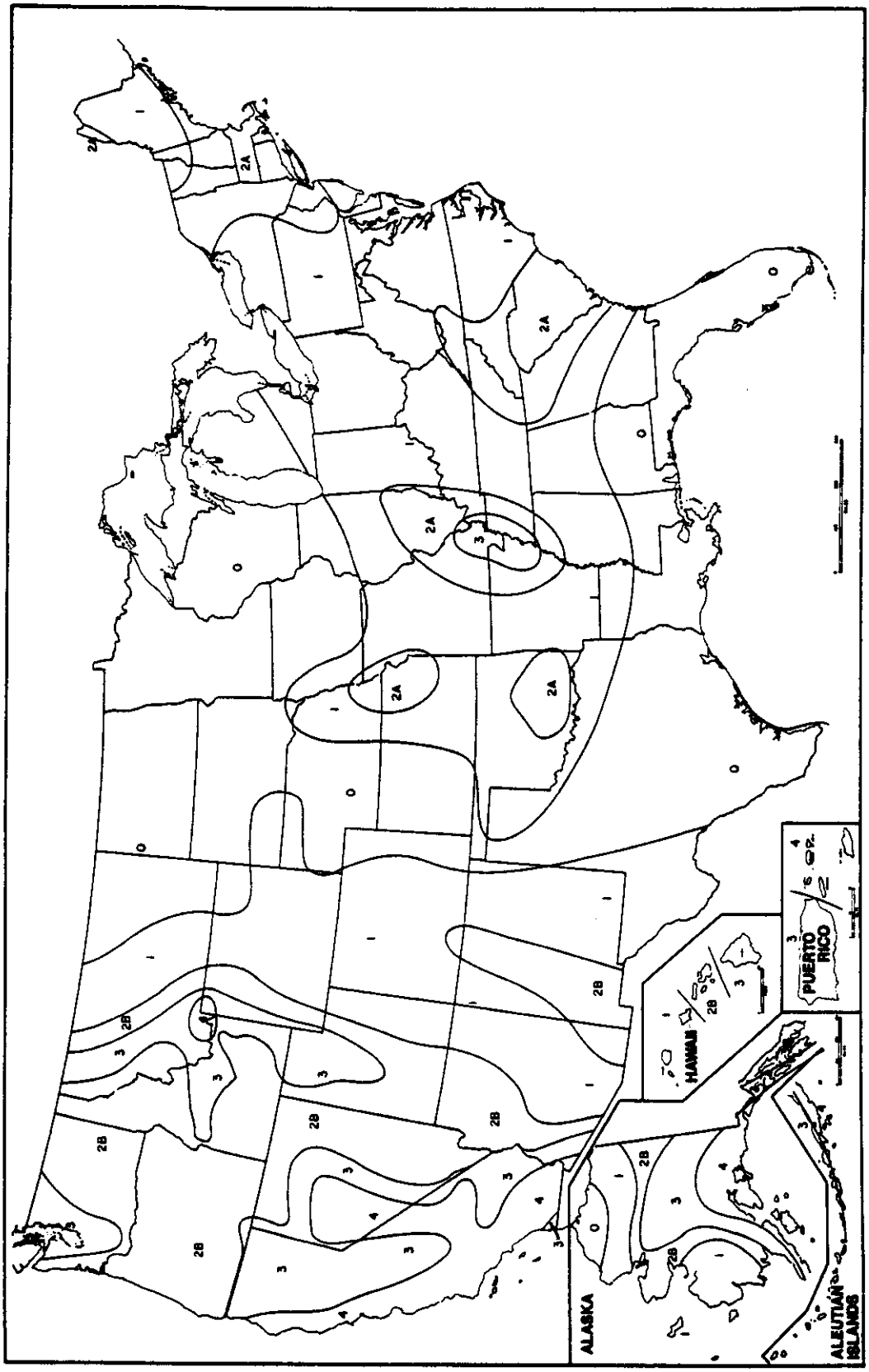


Figure 1

This graph from the Uniform Building Code shows the seismic zone regions of the U.S.

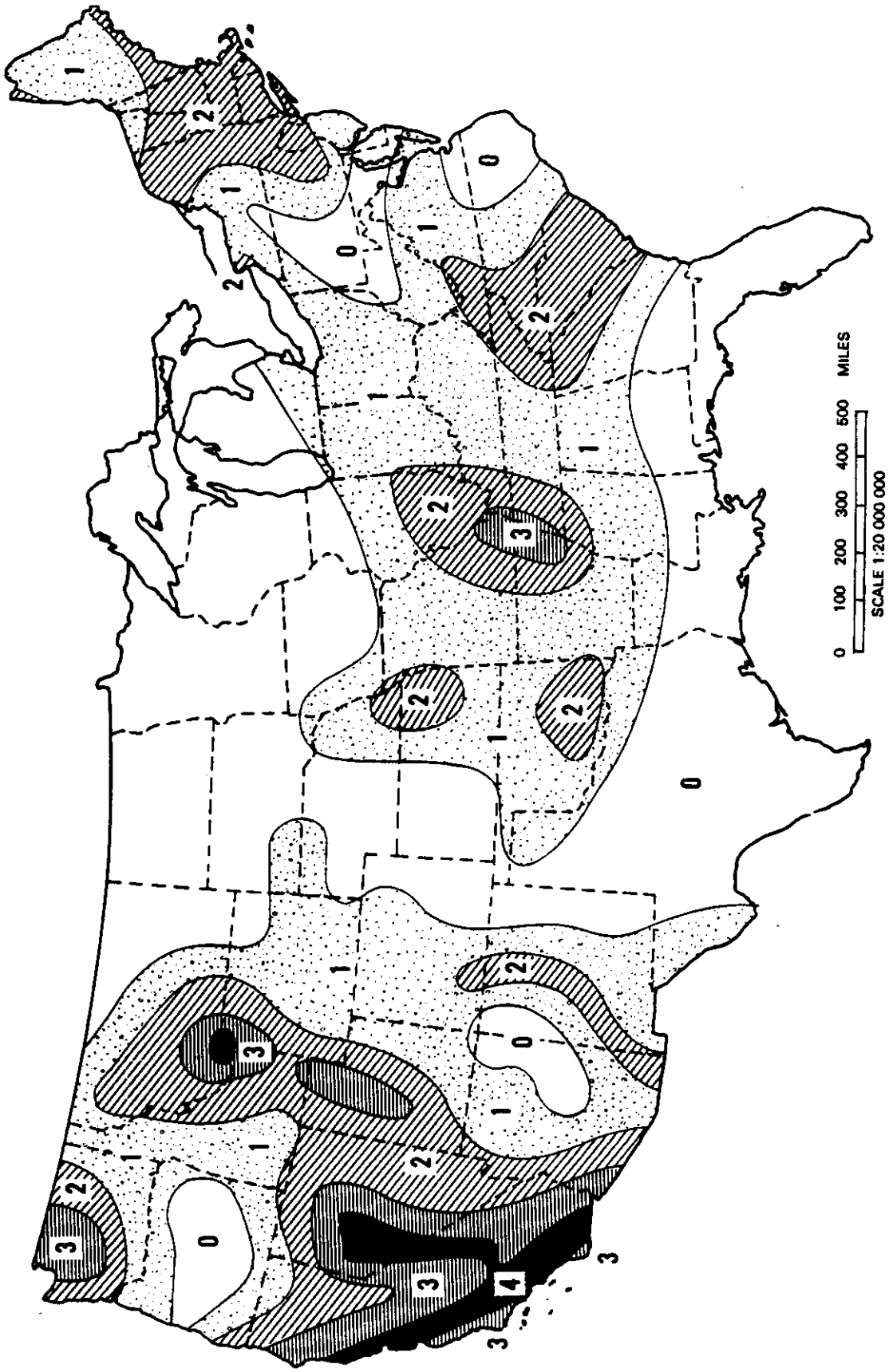
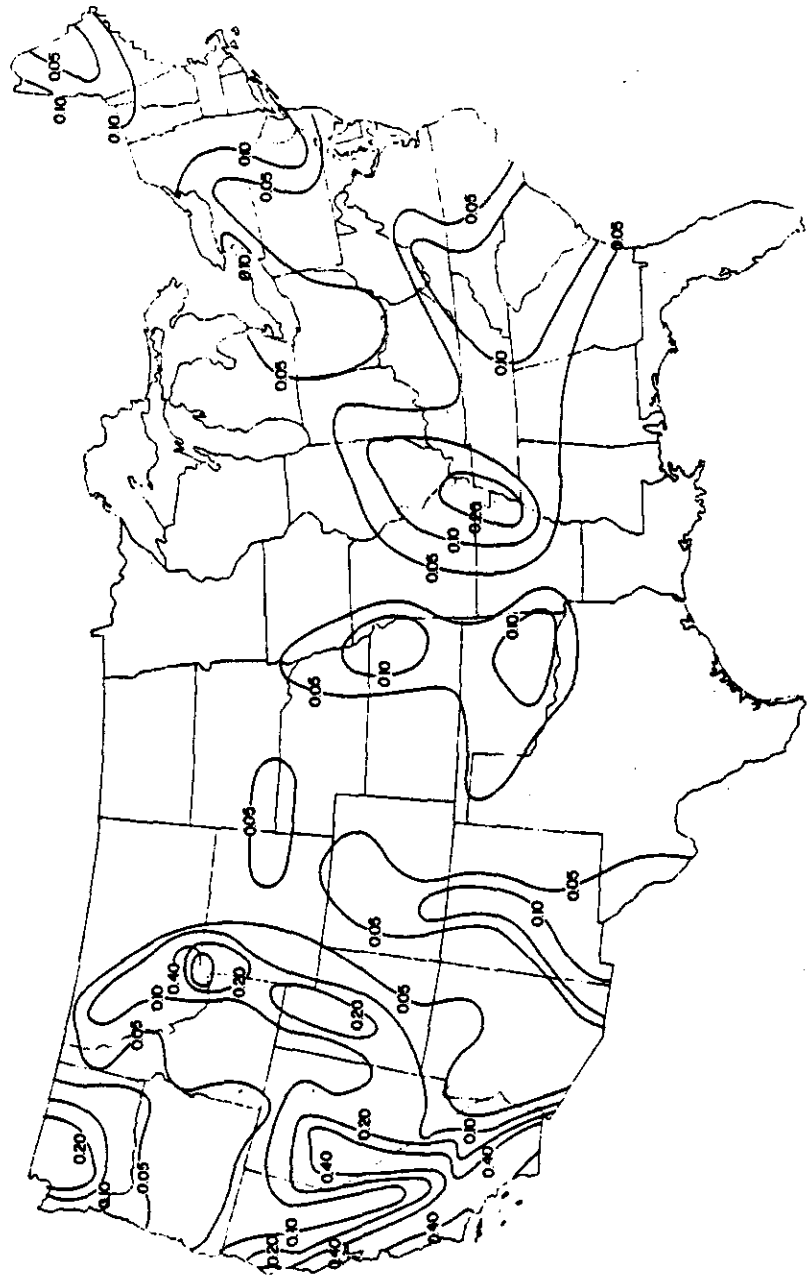


Figure 2

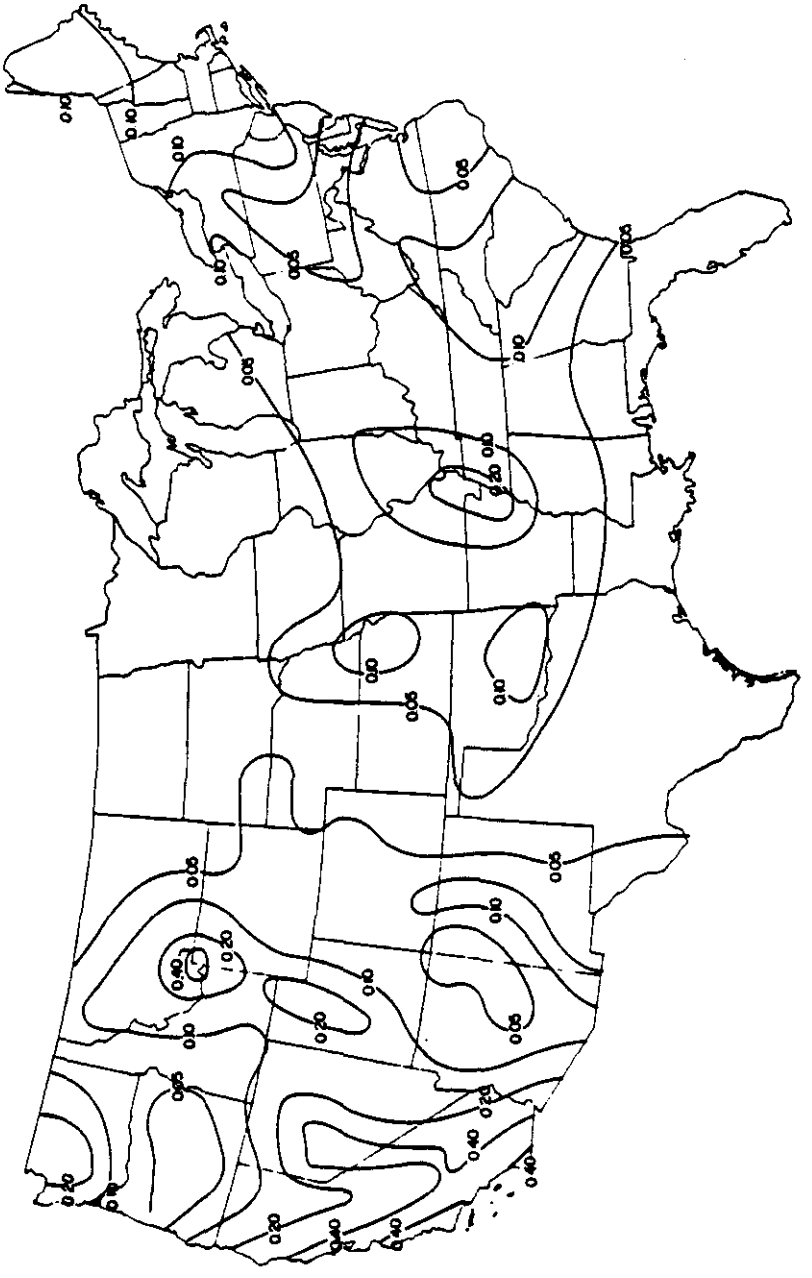
The seismic zone regions for the ASCE 7-88 (ANSI A58.1) are herein depicted.



Note that the numbers on the contours are values of EPA in units of acceleration of gravity. They were used to prepare Map 1 in Chapter 1 of the *Provisions*.

Figure 3

Contours of effective peak acceleration (EPA) for the contiguous United States are given in FEMA 222.



Note that the contours show values of A_v for use in Eq. C1-3.

Figure 4

The effective peak velocity-related acceleration, A_V, is shown in Figure 4 from the FEMA 222.

APPENDIX

32.0 SEISMIC DESIGN

The entire SSC site with all of its facilities is located in Seismic Zone 0, as described in ANSI A58.1 (ASCE 7-88) "Minimum Design Loads for Buildings and other Structures".

The following minimum design requirements for seismic forces on connections of walls or structures are the requirements given by the standard mentioned above.

32.1 Anchorage of Concrete or Masonry Walls

Any floors and/or roofs that provide lateral support shall have concrete or masonry walls anchored to them. A positive direct connection provided by the anchorage should be capable of resisting the horizontal force (Fp) specified by the equation:

$$Fp = Z*I*Cp*Wp$$

Z represents the seismic zone coefficient. All of the facilities of the SSC LABORATORY fall into Zone 0 on the seismic map. This corresponds to a Z value of 0.125.

The Occupancy Importance Factor is denoted by the letter I. The SSC LABORATORY contains a building that has an occupancy of more than 300 people. The standard locates this building in category II, for which I = 1.25. Buildings or structures with smaller occupancy ratings fall in category I, for which I = 1.00.

The horizontal force factor, Cp, is 0.3, because the part or portion of the building connections for prefabricated structural elements other than walls, with force applied at center of gravity or assembly, will be resisted by positive anchorage force, not a frictional force.

The weight of the portion or part of the structure is Wp, which includes the total dead and live load for that section:

$$Fp = 0.125*1.25*0.3*Wp$$
$$Fp = 0.05*Wp.$$

32.2 Load Paths

All parts of the building or structure that transmit seismic force shall be connected through a continuous path to the resisting element. The connection and the elements along the path to the resisting element shall be capable of resisting a minimum force (Fp), determined as the greater force (Fp) from the following equations:

1) $Fp = 0.15*Z*I*Wp$
Seismic Zone 0; $Z = 0.125$, Category II; $I = 1.25$.
$Fp = 0.15*0.125*1.25*Wp$

$Fp = 0.023*Wp$

or

2) $Fp = 0.05*Wp$

Equation two is shown to govern the SSC site. Therefore, the minimum force (Fp) shall be determined by

$$Fp = 0.05*Wp$$

where Wp = Dead load and any applicable live load of the structure.

32.3 Special Structures

The minimum requirements for the SSC Laboratory may not suffice for certain technical components. Special structures that contain large, concentrated masses, high aspect ratios, and unique support requirements, such as large detectors, may exhibit dynamic characteristics that fall outside of this static envelope and so may need to be subjected to additional and more comprehensive response spectrum or time history analysis.

32.4 Additional Considerations

Non-structural components that may be critical to SSC Laboratory operation, such as control units, high voltage electrical equipment, and cryogenic devices may experience secondary damages from seismic loadings due to overturning or failed supporting or anchoring mechanisms. These secondary or non-structural damage potentials may require additional seismic hazard loading considerations.