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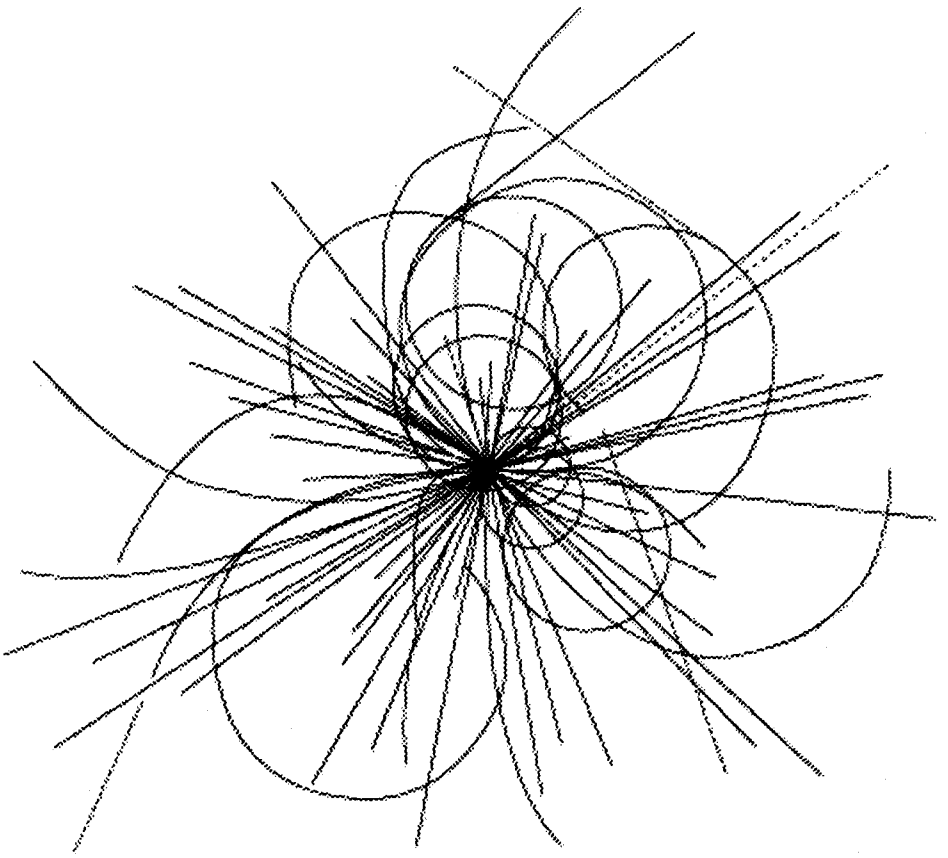

Superconducting Super Collider Laboratory

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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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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.

PURPOSE

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.

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SEISMICITY UNDER DOE 6430.1A GENERAL DESIGN CRITERIA

The Department of Energy (DOE) has published guidelines in order 6430.1A, *United States Department of Energy General Design Criteria* for the design of structures with respect to earthquake and other seismic activities. The Uniform Building Code (UBC) indicates that the SSC Laboratory is located within the Seismic Zone 0, see figure 1. 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 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.

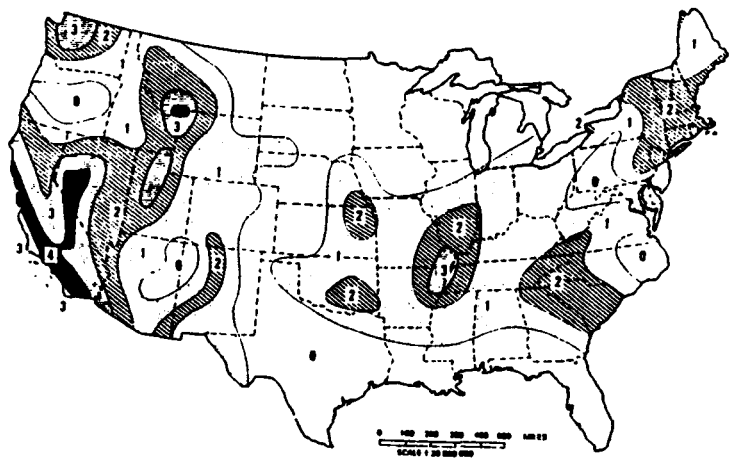

Figure 1. Map for Seismic Zones--Contiguous 48 States (ASCE 7-88; p 33)

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

The seismic zone map of ASCE 7-88 reflects a SSC Laboratory locale of Zone 0.[1] 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.[2]

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:

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

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) for buildings that will house more than 300 people (Category II) is 1.25. The remaining SSC buildings and structures fall within Category I, for which I = 1.0. The Horizontal Force Factor for the SSC Laboratory facilities is defined to be 0.3. 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

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

[2] Ibid., pp 32, 40.

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) or (2):

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

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

$$Fp = 0.023*Wp$$

for equation (2), or

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

for equation (1).

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 imposed by FEMA 222 shall be considered the minimum loading requirements based upon an Effective Peak Acceleration (EPA) of less than 0.05g. This EPA has a 0.1 probability of being exceeded in 50 years. Seismic Hazard Exposure Group I and an EPA = 0.05g categorizes SSC Laboratory facilities.[3] SSC Laboratory facilities fall into Group I because the facilities are not emergency stations nor public places. 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.[4]

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:

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

or

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

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

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

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:

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

or

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

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. 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.

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

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

[4] Ibid., pp 45-6.

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.[5]

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.

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 requirements limitations. The strength of the structural connections must exceed the lateral force (F_p).

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.

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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.
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[5]Ibid., p 46.