Evaluating Seismic Requirements in Specifications

There are four or five items that are critical when determining the extent of seismic restraint required by a specification. Once the need for restraint is determined, the magnitude of the seismic forces must be evaluated to select the required components.

The initial four items affecting all codes are:

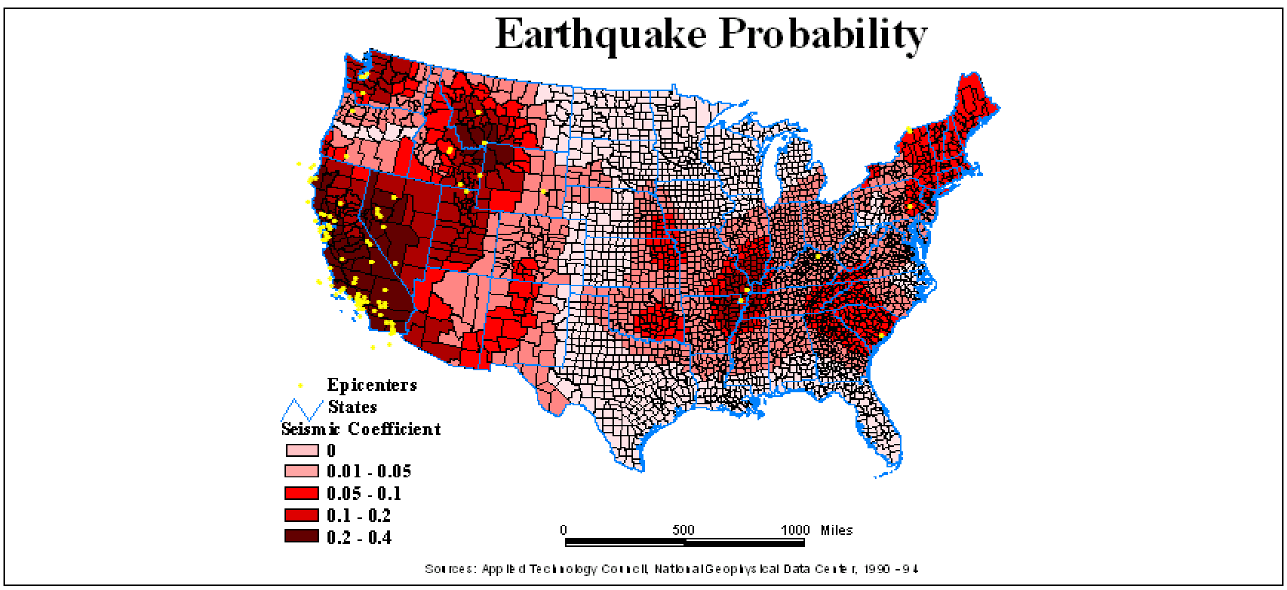
1) The effective national code (code document and year).
2) The location of the project and the ground acceleration coefficient (A_v or Z depending on the code).
3) The occupancy category (essential, hazardous, or emergency service-related in particular).
4) Any special seismic factors that may be listed in the spec and that exceed code requirements. These may dictate restraint even if the code would not normally require it, and a seismic requirement is often added to a spec to afford some degree of bomb blast protection.

A fifth item that affects only the 97 UBC, 2000 IBC, and TI 809-04 spec is:

5) The class of soil present at the jobsite (geotechnical report data).

The above information will need to be applied to the code requirements to determine the extent of seismic restraint to be included in the project. Once the above information is gathered, we can compare it to the appropriate code to determine specific requirements.

A typical map for the BOCA, SBC, and UBC codes is shown below for reference.



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1996 BOCA and 1997 SBC

The last version of both the BOCA and SBC codes, although being phased out by the 2000 IBC code, are still occasionally referenced at the state level or for a specific project. These two codes have basically identical seismic design parameters and will be considered together in this section.

Equipment Exempt from Seismic Requirements

The first step in calculating the seismic requirements for a job is to determine if restraint can be ruled out for the entire project. Start by determining the seismic use (or hazard exposure) group. All structures are placed into one of three classifications:

I – Anything not in Groups II or III
II – High occupancy structures and schools
III – Emergency, hazardous, and essential facilities.

Using the seismic use group, along with the site ground acceleration factor and the table below, a "performance" factor can be obtained. Equipment in buildings with a performance factor of "A" or "B" is exempt from seismic design requirements.

Effective Peak Velocity Related Accelerations	Seismic Hazard Exp Grp I	II	III
$A_v<.05$	A	A	A
$.05<A_v<.10$	B	B	C
$.10<A_v<.15$	C	C	C
$.15<A_v<.20$	C	D	D
$.20<A_v$	D	D	E

Seismic Performance Factor

In addition, mechanical equipment in performance category "C" buildings which falls into seismic use group I occupancies and is not related to safety, emergency power, or hazardous material transfer is also exempt.

Piping does not require restraint in any seismic zone or performance category as long as it is 1) not hazardous, and 2) mounted such that the dimension from the top of the pipe to the supporting surface does not exceed 12" and adequate flexes are included at equipment connections. In addition, if the pipe is under 2-1/2" in diameter and is not in a mechanical room, or if it is under 1-1/4" in diameter and is in a mechanical room, no restraint is required.

Ducting does not require restraint in any seismic zone or performance category as long as it is 1) not hazardous, and 2) mounted such that the pendulum length from the support

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surface to the trapeze does not exceed 12" and adequate flexes are included at equipment connections. Also, if the duct is less than 6 sq ft in area no restraint is required.

In the BOCA and SBC codes there is no specific equipment exemption by weight or mounting location. If there is a requirement in the building to restrain equipment, it must all be restrained without regard to weight.

Estimating Seismic Forces

The global lateral seismic load is

$$F_p = A_v C_c P a_c W_c \qquad \textbf{(Eq. 2.8-1)}$$

where:

F_p = lateral seismic load
A_v = ground acceleration coefficient
C_c = seismic coefficient (Table 2.8-1)
P = performance criteria factor (Table 2.8-1)
a_c = attachment amplification factor
= 2.0 for resiliently mounted equipment above grade
= 1.0 for all others
W_c = equipment/component weight.

Worst-Case Load/Required Restraint Estimates

The worst-case loads can be estimated for preliminary design as:

Lateral Load: 2 * (total lateral load / number of restraints)

Vertical Load: 0 ($F_p < .25W_c$)
$0.5F_p$ ($.25W_c < F_p < .5W_c$)
$1.0F_p$ ($.5W_c < F_p < 1.0W_c$)
$2.0F_p$ ($F_p > 1.0W_c$)

For general guidance, when restraint is required with these codes, FHS and FLSS isolators and 1/4" restraint cables will work in virtually all zones and with most equipment types. For attachment to concrete in higher seismic zones, load spreader plates will almost certainly be required.

For non-hazardous piping and ductwork, a reasonable estimate of the number of restraints required is the total length of restrained pipe divided by 25, or the total length of restrained duct divided by 20. For hazardous systems, the values would be about 3/2 of

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the above.

Table 2.8-1. Seismic Coefficients and Performance Criteria Factors (BOCA and SBC).

Mech / Elec component or system	Cc	P		
		Ssmc Hzrd Grp		
		I	II	III
Fire protection equip and systems	2.0	1.5	1.5	1.5
Emergency or standby electrical systems	2.0	1.5	1.5	1.5
General Equipment A) Boilers, furnaces, incinerators, water htrs, and other equipment utilizing combustible energy sources or high-temperature energy sources B) Communication systems C) Electrical bus ducts and primary cable systems suspended farther than 12" from supporting surface or 2-1/2" or more inside diameter D) Electrical motor control centers, motor control devices, switchgear, transformers, and unit substations E) Reciprocating or rotating equipment F) Tanks, heat exchangers and pressure vessels.	2.0	0.5	1.0	1.5
Manufacturing and process machinery	0.67	0.5	1.0	1.5
Pipe systems				
A) Gas and high-hazard piping	2.0	1.5	1.5	1.5
B) Fire suppression piping	2.0	1.5	1.5	1.5
C) Other pipe systems	0.67	0.5	1.0	1.5
HVAC ducts	0.67	0.5	1.0	1.5
Electrical panel boards	0.67	0.5	1.0	1.5
Lighting fixtures (Cc for pendulum fixtures must be 1.5)	0.67	0.5	1.0	1.5

1997 UBC

The 97 UBC code is considerably more complex than the BOCA or SBC codes. This code introduces soil factors, equipment elevation, and fault proximity into the equation.

Equipment Exempt from Seismic Requirements

When determining the seismic requirements the first step, as with BOCA and SBC, is to review the job to see if restraint can be ruled out of the project globally. The 97 UBC code contains only a single global exclusion. All components in buildings constructed in seismic zones 2 and higher must be designed for seismic loads. By exclusion, this indicates that components in all buildings constructed in seismic zone 1 ($Z < .075$) need not be reviewed for seismic loads.

The 97 UBC excludes equipment weighing 400 lb or less which is floor or roof mounted. For equipment meeting this exclusion it need be restrained only in the manner normally recommended for general applications by the equipment manufacturer. No engineering support documentation is required to substantiate the design and no special components

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are required.

Piping does not require restraint in any zone as long as it is 1) not hazardous, and 2) mounted with a swivel-type connection such that the dimension from the top of the pipe to the supporting surface does not exceed 12" and adequate flexes are included at equipment connections.

Ducting does not require restraint in any seismic zone or performance category as long as it is mounted with a swivel-type connection such that the pendulum length from the support surface to the trapeze does not exceed 12" and adequate flexes are included at equipment connections.

Raceways do not require restraint in any seismic zone or performance category as long as they are mounted with a swivel-type connection such that the pendulum length from the support surface to the raceway does not exceed 12" and adequate flexes are included at equipment connections.

Although not in the code, it is accepted practice to not restrain piping outside of mechanical rooms that is under 2-1/2" in diameter or ductwork that is under 6 sq ft in area. This is referenced in the SMACNA guidelines and these guidelines have been accepted by the UBC as meeting code compliance. These can be excluded if SMACNA is referenced in the specification.

Estimating Seismic Forces

The lateral seismic force acting on a component or piece of equipment is calculated as

$$F_p = \frac{a_p C_a I_p}{R_p}\left(1 + 3\frac{h_x}{h_r}\right)W_p \qquad \textbf{(Eq. 2.8-2)}$$

where:

F_p = total design lateral force
a_p = component amplification factor (Table 2.8-2)
C_a = seismic coefficient
I_p = importance factor
R_p = component response modification factor (Table 2.8-2)
h_x = component attachment elevation with respect to grade
h_r = roof elevation with respect to grade
W_p = weight of component.

The design lateral force need not exceed

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$$F_p = 4.0 C_a I_p W_p$$ **(Eq. 2.8-3)**

and the absolute minimum design load is

$$F_p = 0.7 C_a I_p W_p .$$ **(Eq. 2.8-4)**

In any case, if the equipment is anchored to concrete the load can be reduced by a factor of 1.4 to account for the different design factors used for the anchor capacity and load determination (this applies to either hard-mounted or isolated equipment). If the equipment is isolated *and* anchored to concrete with post installed or shallow (less than 8 bolt diameter) cast-in-place anchors, the design load used must be doubled to account for dynamic impact.

The importance factor I_p for a piece of equipment is 1.5 if the equipment is essential to the continued operation of essential or hazardous services (whether or not the building itself is essential). Otherwise the importance factor is 1.0.

Table 2.8-2. Component Amplification and Response Modification Factors.

Horizontal Force Factors		
Components	a_p	R_p
Ceilings and light fixtures	1	3
Equipment		
Tanks and vessels	1	3
Elec, mech, plumbing equip, conduit, piping, ductwork	1	3
All equip anchored to structure below its center of mass	2.5	3
Emergency systems and essential communications	1	3
Isolated equipment	2.5	1.5

The seismic coefficient (C_a) is a measure of the ground motion acceleration and its calculation requires the following information.

1) The Site Ground Acceleration Coefficient (z). This will range from .075 to .4 depending on location.
2) The Site Soil Classification (Hard Rock - S_A, Rock - S_B, Dense Soil - S_C, Stiff Soil - S_D, Soft Soil - S_E, and Other - S_F). If unknown, use soil profile S_D.
3) If the Site Ground Acceleration Coefficient (z) is 0.4 (Seismic Zone 4) the proximity to the nearest active fault is required. Fault maps can be pulled up on the Internet to help in this task, but it should be specified by the Engineer of Record. If the distance to the fault is greater than 10 km, the forces are not increased. If less than 10 km, the distance in km should be estimated.
4) If the Site Ground Acceleration Coefficient (z) is 0.4 (Seismic Zone 4) the seismic source type must be identified. A – faults that are capable of producing large magnitude earthquakes and that have a high rate of seismic activity. C – faults not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity. B – all other faults.

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The Seismic Coefficient is determined from Table 2.8-3b. The table is entered with the Seismic Zone Factor and Soil Profile and the value of C_a is determined. In Seismic Zone 4 (z = 0.4) the Near Source Factor (N_a) should be determined from Table 2.8-3a.

Table 2.8-3. Near Source Factor and Seismic Coefficient.

(a) Near Source Factor

Near Source Factor (N_a)			
Seismic Source Type	Closest Distance to know Seismic Source		
	<= 2 km	5 km	>= 10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

Linear Interpolation for distance is permitted

(b) Seismic Coefficient

Seismic Coefficient C_a					
Soil Profile Type	Seismic Zone Factor, z				
	z = 0.075	z = 0.15	z = 0.2	z = 0.3	z = 0.4
Sa	0.06	0.12	0.16	0.24	$0.32N_a$
Sb	0.08	0.15	0.20	0.30	$0.40N_a$
Sc	0.09	0.18	0.24	0.33	$0.40N_a$
Sd	0.12	0.22	0.28	0.36	$0.44N_a$
Se	0.19	0.30	0.34	0.36	$0.36N_a$
Sf	Site Specific Geotechnical Report Required				

Worst-Case Load/Required Restraint Estimates

The worst-case loads can be estimated for preliminary design as:

Lateral Load: 2 * (total lateral load / number of restraints)

Vertical Load: 0 ($F_p < .25W_p$)
$0.5F_p$ ($.25W_p < F_p < .5W_p$)
$1.0F_p$ ($.5W_p < F_p < 1.0W_p$)
$2.0F_p$ ($1.0W_p < F_p < 2.0W_p$)
$4.0F_p$ ($F_p > 2.0W_p$)

When restraint is required with this code, FHS and FLSS isolators and 1/4 inch restraint cables will generally work for “at grade” applications in virtually all zones and with most equipment types. For equipment locations at higher elevations and the roof, particularly in higher seismic zones, it may be necessary to use separate restraints (HS-5 or 7) or FMS isolator/restraints. If attached to concrete, load spreader plates will almost certainly be required.

For non-hazardous piping and ductwork at grade, a reasonable estimate of the number of restraints required is the total length of restrained pipe divided by 20 and the total length of restrained duct divided by 15. For hazardous systems the values would be about 3/2 the above. For piping and duct at the roof, the required restraints will approximately double. For pipes over 6” diameter in all cases cable sizes will increase to 3/8” and for

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pipes over 12” diameter the size can increase to 1/2".

2000 IBC and TI 809-04

This code and federal spec represent the latest round of thinking in seismic design. They are similar to the 97 UBC but use new maps and factors to allow more accurate load assessments at a given site without having to research fault information. Soil factors and equipment elevation still factor into the equation.

The primary difference between TI 809-04 and the 2000 IBC is in the area of exclusions. The 2000 IBC excludes some structures and components from the seismic design scope that TI 809-04 does not.

Equipment Exempt from Seismic Requirements

As with all building codes, the first step in calculating the seismic requirements for a job is to determine if restraint can be ruled out for the entire project.

The **2000 IBC** exempts components from the seismic requirements as follows:

Entire Structures (and contents):

1) Group R-3, single-family, stand-alone residential structures not more than three stories in height, in areas where the mapped S_{DS} value is less than .5g.
2) Agricultural storage structures intended only for incidental human occupancy.
3) All structures where the mapped S_{DS} value is less than .167g and the mapped S_{D1} value is less than .067g.

Mechanical/Electrical Components and Architectural Elements:

1) All non-structural mechanical components and architectural elements in structures that fall into seismic design category A or B.
2) All mechanical components in structures that fall into seismic design category C and where the importance factor is 1.0
3) All architectural elements in structures that fall into seismic design category C and where the importance factor is 1.0, and there are fewer than three stories.

Specific Mechanical/Electrical Equipment:

1) All components (no matter what seismic design category) with an importance factor of 1.0 weighing less than 400 lb, mounted to the floor with legs under 4’ in height, connected via flexible connections between components and associated ductwork, piping, etc., and not critical to the continued operation of the structure.

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2) Mechanical and electrical components in seismic design categories D and E that weigh 20 lb or less (no matter where mounted), that are connected via flexible connections between components and associated ductwork, piping, etc., where the importance factor does not exceed 1.0.
3) Ductwork that is less than 6 sq ft in area for the full length of a run where the importance factor does not exceed 1.0 (no matter what seismic design category) and the motion induced by a seismic event will not result in contact with other components.
4) All ductwork that is suspended on hangers 12" or less in length for the full length of a run with a non-moment generating connection to the structure and where the importance factor does not exceed 1.0 (no matter what seismic design category) and motion induced by a seismic event will not result in contact with other components.
5) High deformability piping in all seismic design categories that is 3.0 inches or less in diameter and has an importance factor of 1.0. (Note: High deformability is a measure of ductility as defined in the code section 1602.1.) (Note: if trapeze mounted and the cumulative total area of the pipes supported is less than 5", no restraint is required.)
6) High deformability piping in seismic design category C that is 2.0 inches or less in diameter with an importance factor of 1.5. (Note: if trapeze mounted and the cumulative total area of the pipes supported is less than 3.2", no restraint is required.)
7) High deformability piping in seismic design category D or E that is 1.0 inch or less in diameter, with an importance factor of 1.5.
8) All piping that is suspended on hangers 12" or less in length (from the top of the pipe) with a non-moment generating (swivel) connection to the structure, for all importance factors and seismic eesign categories.
9) Any component that is supported from above by chains or other non-moment generating connection provided it cannot be damaged by or cannot damage any other component and has a supporting connection designed to take at least three times the operating weight.

<u>Specific Architectural Elements:</u>

1) Components supported on chains or otherwise suspended from the structural system above, as long as they are capable of moving a minimum of 12" or a swing of 45 degrees without damage or contact with an obstruction, and as long as the gravity design load used when sizing the attachment hardware is 3g.
2) Seismic load of less than 5 psf.

<u>Other:</u>

1) Equipment installed in line and hard mounted to the ductwork that weighs 75 lb or less can be restrained as though it is part of the duct (no separate restraints

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are required).

There are considerably fewer exemptions from seismic restraint design in the **TI 809-04** Code. There are no exemptions for entire structures or general equipment types and there are only a few for specific components as follows:

Specific Mechanical Equipment:

1) Piping in seismic design category A.
2) Piping in seismic design category B in structures that are not categorized as essential or hazardous.
3) Gas piping under 1” diameter.
4) Piping in boiler and mechanical rooms of less than 1-1/4” diameter.
5) All other piping of less than 2-1/2” diameter.
6) All electrical conduit of less than 2-1/2” diameter.
7) Ductwork that is less than 6 sq ft in area .
8) All ductwork that is suspended on hangers 12” or less in length for the full length of a run with a non-moment generating connection to the structure.
9) All piping that is suspended on individual hangers 12” or less in length (from the top of the pipe) with a non-moment generating (swivel) connection to the structure.

Estimating Seismic Forces

The lateral seismic force acting on a component or piece of equipment in both the 2000 IBC and TI 809-04 is calculated as

$$F_p = \frac{0.4 a_p S_{DS}}{R_p / I_p}\left(1 + 2\frac{z}{h}\right) W_p \qquad \textbf{(Eq. 2.8-5)}$$

where:

F_p = total design lateral force
a_p = component amplification factor (Table 2.8-4)
S_{DS} = design spectral response acceleration at short periods
I_p = component importance factor
R_p = component response modification factor (Table 2.8-4)
z = component attachment elevation with respect to grade
h = average roof elevation with respect to grade
W_p = weight of component.

The design lateral force need not exceed

$$F_p = 1.6 S_{DS} I_p W_p \qquad \textbf{(Eq. 2.8-6)}$$

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and the absolute minimum design load is

$$F_p = 0.33 S_{DS} I_p W_p \, . \qquad \textbf{(Eq. 2.8-7)}$$

The Component Amplification (a_p) and Response Modification (R_p) factors are shown in Table 2.8-4. When anchoring components to concrete using shallow embedment anchors (those with an embedment length-to-diameter ratio of less than 8), an R_p value of 1.5 is to be used and overides the value identified in the Component Coefficient table.

Table 2.8-4. Component Amplification and Response Modification Factors.

Component Coefficients

Mechanical and Electrical Component or Element	a_p	R_p
General Mechanical		
Boilers and furnaces	1.0	2.5
Pres vessels, stacks, cantilevered chimneys	2.5	2.5
Other	1.0	2.5
Mfg and Process Equipment		
General	1.0	2.5
Conveyors	2.5	2.5
Piping		
High deformability elements and attachments	1.0	3.5
Limited deformability elements and attachments	1.0	2.5
Low deformability elements or attachments	1.0	1.25
HVAC Equipment		
Vibration isolated	2.5	2.5
Non-vibration isolated	1.0	2.5
Mounted in line with ductwork	1.0	2.5
Elevator & Escalator Components	1.0	2.5
Trussed Towers	2.5	2.5
General Electrical		
Distribution systems	1.0	3.5
Equipment	1.0	2.5
Lighting Fixtures	1.0	1.25
Architectural Component or Element		
Interior Non-Structural Walls and Partitions		
Plain (unreinforced) masonry	1.0	1.25
Other	1.0	2.5
Ceilings	1.0	2.5
Access Floors		
Floors (built on and affixed to seismic frame)	1.0	2.5
Other	1.0	1.25
Flexible Components		
High deformability	1.0	3.5
Limited deformability	2.5	2.5
Low deformability	2.5	1.25

The importance factor in the 2000 IBC or TI 809-04 document is now tied more closely to the use of the equipment rather than the use of the structure. There are two levels of

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importance: 1.0 and 1.5. The importance factor of 1.5 is used under the following conditions:

1) The component is a life-safety component that must function after an earthquakea
2) The component contains hazardous or flammable material in excess of exempted limits.
3) Storage racks in structures that are open to the public (Home Depot for example).
4) Components needed for continued operation of Group III occupancy structure.

All other conditions use an importance factor of 1.0.

Determination of the seismic response spectral acceleration at short periods (S_{DS}) requires the use of a spectral response map. Current maps applicable to either specification can be quite detailed and unreadable in a small scale. To avoid this problem, dynamic maps can be downloaded from the following website: http://geohazards.cr.usgs.gov/eq/design/ibc/IBC1615-1us.pdf. For evaluating the attachment of equipment and architectural components, the maps of interest are those that list the maximum short period spectral response (.2 second). The maps identifying maximum long period spectral response (1 second) are of interest to us only to determine if the structure can be exempted (IBC applications only) from seismic analysis and would only come into play if the design spectral response at short period (.2 second) is less than 0.167.

It must be noted that the maps indicate the maximum spectral response for long and short periods (S_{MS} & S_{MI}) and not the design spectral response. The ground accelerations used for the design of architectural and equipment attachment are the short period (.2 second) values only (S_S). These are multiplied by the site (soil) classification factor (F_a) from the table below (2.8-5a) and then reduced by a factor of 2/3 except in the case of immediate occupancy structures under TI 809-04. In the TI 809-04 immediate occupancy case (A) the reduction factor is increased to 3/4. The result, the design spectral response at short periods (S_{DS}) is the final acceleration coefficient used in the design.

Levels of seismic concern are identified in the new code as the seismic design category. These are a function of the structure's end use and the ground acceleration coefficient. A rough definition of the three possible use groups (I, II, and III) is as follows: Group III is an emergency treatment, an essential service structure or a structure containing potentially hazardous material; Group II is a high occupancy structure or non-essential utilities;; Group I is what is left. Table 2.8-5b indicates the seismic design categories for various conditions.

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Table 2.8-5. Site Factors and Seismic Design Categories.

(a) Site Factors

Site Factor (F_a) Based on Site Class and Mapped Spectral Response for Short Periods (S_s)[a]						
Site Class	**Soil Type**	**Mapped Spectral Response Accel at Short Periods**				
		$S_s \le 0.25$	**$S_s = 0.50$**	**$S_s = 0.75$**	**$S_s = 1.0$**	**$S_s \ge 1.25$**
A	Hard Rock	0.8	0.8	0.8	0.8	0.8
B	Moderate Rock	1	1	1	1	1
C	Dense Soil, Soft Rock	1.2	1.2	1.1	1	1
D[c]	**Stiff Soil**	**1.6**	**1.4**	**1.2**	**1.1**	**1**
E	Soft Soil, Clay	2.5	1.7	1.2	0.9	Note b
F	Fill and Other	Note b	Note b	Note b	Note b	Note b

[a] Use straight line interpolation for intermediate values of mapped spectral acceleration

[b] Site specific geotechnical investigation and dynamic site response analyses shall be performed to determine values

[c] In lieu of geotechnical data and in cases where Site Class E or F are not expected, Site Class D shall be assumed.

(b) Seismic Design Category

Seismic Design Category based on .2 Second Response Accelerations			
S_{DS} Value	Seismic Use Group		
	I	II	III
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33 \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D
$0.75g \le S_1$[a]	E	E	F

[a] S_1 is Mapped Max Considered Spectral Response

Vertical Force Component

It can be assumed that a vertical force component must be factored into the restraint analysis for most situations. The vertical force to be used is

$$F_{pv} = 0.2 S_{DS} \qquad \textbf{(Eq. 2.8-8)}$$

Force Tailoring Factors

In order to apply the above forces, there are additional factors that may be applicable, depending on the component being analyzed and the method of attachment used.

1) As with the 97 UBC, the forces obtained from the above equations are working strength figures. Because of this, the forces can be reduced by a factor of 1.4 when computing concrete anchorage loads (working stress-based ratings). It comes into play when evaluating connections using the older ASD (Allowable Stress Design) bolt allowables, connections to timber with lag screws, or connections to concrete with post installed anchors.
2) Permitted design loads and the resulting stresses in the attachment hardware can be increased by a factor of 1.33 for short-term wind and seismic load applications when working with working stress-based allowables.
3) Shallow embedment anchors must be sized to withstand 1.95 (or 1.3 x R_p (where R_p equals 1.5)) times the computed design load.
4) For mechanical or electrical equipment that is supported on vibration isolation systems, the design lateral force shall be taken as 2 F_p.

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Consolidating the above into simple understandable equations, we get the following:

Using the previously determined design force F_p, steel bolt and fastener allowables as per LFRD, ASD and/or published post installed anchor allowables per ICBO

1) Rigid Equipment Connection via Through Bolts using the ASD Bolt Allowables:

   Lateral Design Load = F_p / 1.4, but increase bolt allowables by multiplying by 4/3
   Vertical Design Load = F_{pv} / 1.4, but increase bolt allowables by multiplying by 4/3

2) Rigid Equipment Connection to Concrete with Post-Installed Anchors using ICBO Anchor Ratings (Non OSHPD Applications):

   Increase all anchor allowables by multiplying by 4/3 in all cases.

   Shallow embed anchors (< 8 dias)

   Lateral Design Load = 1.95F_p / 1.4
   Vertical Design Load = 1.95F_{pv} / 1.4

   Standard embed anchors (>= 8 dias)

   Lateral Design Load = 1.3F_p / 1.4
   Vertical Design Load = 1.3F_{pv} / 1.4

3) Rigid Equipment Connection to Concrete with Post Installed Anchors using ICBO Special Inspection Anchor Ratings (OSHPD Applications):

   Shallow embed anchors (< 8 dias)

   Lateral Design Load = 1.95F_p / 1.4
   Vertical Design Load = 1.95F_{pv} / 1.4

   Standard embed anchors (>= 8 dias)

   Lateral Design Load = 1.3F_p / 1.4
   Vertical Design Load = 1.3F_{pv} / 1.4

4) Rigid Equipment Connection to Wood with Lag Screws as rated per ASD:

   Lateral Design Load = F_p / 1.4, but increase Lag Screw Allowables by 1.6
   Vertical Design Load = F_{pv} / 1.4, but increase Lag Screw Allowables by 1.6

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5) Isolated Equipment Connection via Through Bolts using the ASD Bolt Allowables:

Increase Bolt Allowables by multiplying by 4/3 in all cases.

Lateral Design Load = $2F_p / 1.4$
Vertical Design Load = $2F_{pv} / 1.4$

6) Isolated Equipment Connection to Concrete with Post Installed Anchors using ICBO Anchor Ratings (Non OSHPD Applications):

Increase Anchor Allowables by multiplying by 4/3 in all cases.

Shallow embed anchors (< 8 dias)

Lateral Design Load = $3.9F_p / 1.4$
Vertical Design Load = $3.9F_{pv} / 1.4$

Standard embed anchors (>= 8 dias)

Lateral Design Load = $2.6F_p / 1.4$
Vertical Design Load = $2.6F_{pv} / 1.4$

7) Isolated Equipment Connection to Concrete with Post Installed Anchors using ICBO Special Inspection Anchor Ratings (OSHPD Applications):

Shallow embed anchors (< 8 dias)

Lateral Design Load = $3.9F_p / 1.4$
Vertical Design Load = $3.9F_{pv} / 1.4$

Standard embed anchors (>= 8 dias)

Lateral Design Load = $2.6F_p / 1.4$
Vertical Design Load = $2.6F_{pv} / 1.4$

8) Isolated Equipment Connection to Wood with Lag Screws as rated per ASD:

Increase Lag Screw Allowables by multiplying by 1.6 in all cases.

Lateral Design Load = $2F_p / 1.4$
Vertical Design Load = $2F_{pv} / 1.4$

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Special Anchorage Requirements

With the exception of undercut anchors, expansion anchors shall not be used to attach non-vibration isolated equipment rated at over 10 hp. Conventional wedge-type, post-installed anchors are acceptable for isolated equipment as long as they meet the load requirements as defined here.

For general guidance, when restraint is required with this code, FHS and FLSS isolators as well as 1/4” restraint cables will work for “at grade” applications in lower level (below 1g) zones and with most equipment types. For equipment locations in more severe zones and/or at higher elevations and the roof, particularly in higher seismic zones, it will likely be necessary to use separate restraints (HS-5 or 7) or FMS isolator/restraints. If attached to concrete, load spreader plates will be required.

For non-hazardous piping and ductwork at grade, a reasonable estimate of the restraints required is (for piping) the total length of restrained pipe divided by 20 and (for ductwork) the total length of restrained duct divided by 15. For hazardous systems, the values would be about 2/3 of the above. For piping and duct at the roof, these spacings will decrease to about half of the above values. For pipes over 6” diameter in all cases, cable sizes will increase to 3/8” and for pipes over 12” diameter, the size can increase to 1/2”.

In higher seismic areas, the use of anchor bolts will be heavily restricted, not only because of severe limitations for their use on equipment over 10 hp, but also because of factors that dictate more severe design load magnitudes when they are used. The higher loads require larger anchors and the larger anchors require greater embedment depths. If an embedment depth of under 8 bolt diameters is required due to slab thickness limitations, the design load is again doubled and the idea of using concrete anchors can be effectively eliminated. This leaves through-bolting through the slab as the only viable option.

Unless housekeeping pads are monolithic to the floor slab, their added thickness cannot be included in the embedment depth. Therefore, an anchor that penetrates a 6” housekeeping pad and extends 2” into the structural floor slab is considered to have an embedment depth of 2” instead of 8”. Significant pre-planning is needed to ensure that the problems that can result from these situations are adequately addressed.

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