Evaluating Seismic Requirements in Specifications

Updated April 29, 2003

When reviewing a Specification, there are 4 or 5 items that are critical in determining the extent of the seismic componentry that will be required. Once the need for restraint is determined, the magnitude of the restraint must be evaluated to select the actual components.

The initial 4 items affecting all codes are:

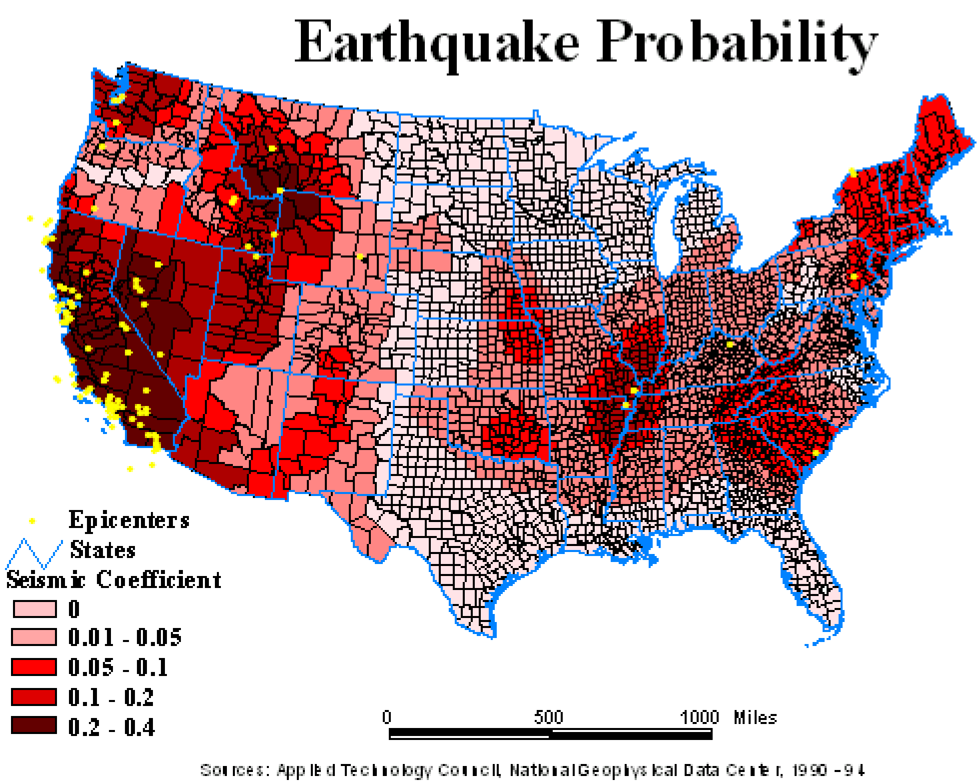
1) The effective national Code that applies (Code document and year)
2) The location of the project and ground acceleration coefficient (A_v or Z depending on the code.)
3) The type of occupancy (in particular is it essential, hazardous, or emergency service related).
4) Any special seismic factors that 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).

And 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 up, we can compare it to the appropriate code to gather specifics.

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



1996 BOCA and 1997 SBC: Beginning with the 2 oldest codes currently referenced at the state level, we find the last version of both the BOCA and SBC codes. These two codes have basically identical seismic design parameters and both are being phased out by the 2000 IBC code.

Initially, review the job to see if restraint can be ruled out of the project globally.

The first step in the process is to determine the Seismic Use (or Hazard Exposure) Group. This should fall into 1 of 3 classifications.

I – Anything not in Groups II or III.
II – High occupancy structures and schools.
III - Emergency, Hazardous, and Essential facilities.

Using this input and applying it to the table below along with the site ground acceleration factor, 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	Siesmic Hazard Exp Grp		
Related Accelerations	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 fall 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, 3) 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 surface to the trapeze does not exceed 12” and adequate flexes are included at equipment connections. Also, 3) if the Duct is under 6 sq ft in area, no restraint is required.

In the BOCA and SBC codes, there is no specific equipment exemption by weight of 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:

To estimate Seismic forces a performance criteria factor is required. Refer to the table below to select the appropriate factor:

The global lateral g load can be initially estimated as follows:

- For hard mounted equipment – Av * Cc * P
- For resilient mounted equipment at grade – Av * Cc * P
- For resilient mounted equipment above grade – 2* Av * Cc * P

The total lateral load would then be the equipment weight multiplied by this final factor.

For restraint load estimates
Worst case lateral load is:

The total lateral load / number of restraints * 2

Worst case vertical load is:

For horizontal g < .25, vertical load is 0
For .25 < horizontal g < .5, vertical load is .5 * horizontal load
For . 5 < horizontal g < .75, vertical load is equal to the horizontal load
For horizontal g > 1.0, vertical load is 2 * horizontal load

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 further 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

For general guidance, when restraint is required with these codes, FHS and FLSS isolators as well as ¼" restraint cables will work in virtually all zones and with most equipment types. If attached 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 restraints required is (for piping) the total length of restrained pipe divided by 25 and (for ductwork) the total length of restrained duct divided by 20. For hazardous systems, the values would be about 2/3 of the above.

1997 UBC: The 97 UBC code is considerably more complex than are the BOCA and SBC codes. This code introduces soil factors, equipment elevation and fault proximity into the equation.

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 one global exclusion. This indicates that all components in buildings constructed in seismic zones 2 and higher must be designed. By exclusion, that indicates that components in all buildings constructed in Seismic Zone 1 (Z < .075) need not be reviewed.

The 97 UBC contains an exclusion for equipment weighing 400 lb or less and which is floor or roof mounted. This exclusion indicates that, when confronted by this equipment, it need only be restrained 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 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 spec.

Estimating Seismic forces:

To begin with, the basic ground motion acceleration (C_a) must be determined. This requires the following input.

1) The site ground acceleration coefficient (z). This will range from .075 to .4 depending on location.
2) The site soil classification (Hard Rock-"Sa", Rock-"Sb", Dense Soil-"Sc", Stiff Soil-"Sd", Soft Soil-"Se", and Other-"Sf"). If unknown, use "Sd".
3) If the site ground acceleration coefficient (z) is .4, then the proximity to the nearest active fault is required. Fault maps can be pulled up on the internet to help in this task. If the Fault is greater than 10 km, it is a non-issue. If less than 10 km, the distance in km should be estimated.
4) If the site ground acceleration coefficient (z) is .4, then 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.

Step one in determining the design ground acceleration is to use the table below along with the proximity and source type information to determine the factor N_a.

Near Source Factor (N_a)			
	Closest Distance to know Seismic Source		
Seismic Source Type	<= 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

Using the N_a determined above, the basic ground motion acceleration (C_a) can be determined from the table below:

Seismic Coefficient C_a					
	Seismic Zone Factor, z				
Soil Profile Type	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				

This factor now has to be tailored to individual equipment types, mountings and locations in the building structure. In order to do this, some specifics are required on the equipment.

1) Equipment Type (what is it?)
2) Importance factor of Equipment
3) Roof Elevation of Building (h_r)
4) Elevation of equipment mounting point in Building (h_x)
5) Is the Equipment Isolated
6) Is the Equipment anchored to concrete?

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 it is 1.0.

For a particular piece of equipment (ignoring anchorage for the moment), the maximum effective seismic design acceleration is:

$$4 * C_a * I_p$$

If the value of the following equation is less, it can be used in place of the above. In higher seismic areas and particularly if the equipment is not located on the roof, it can reduce the loads significantly.

$$a_p * C_a * I_p / R_p * (1 + 3 * (h_x / h_r))$$

a_p and R_p can be drawn from the table below:

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

Under no circumstances can the seismic design acceleration be less than:

$$0.7 * C_a * I_p$$

If the equipment is anchored to concrete, because the anchor rating and the load factors are now based on different design factors, the load can be reduced by a factor of 1.4 (this applies to either hard mounted or isolated equipment).

If the equipment is isolated and only if it is anchored to concrete with post installed or shallow (less than 8 bolt diameter) cast in place anchors, the design load used must be doubled the above for dynamic impact reasons.

The total lateral load would then be the equipment weight multiplied by this final factor.

For restraint load estimates
Worst case lateral load is:
    The total lateral load / number of restraints * 2
Worst case vertical load is:
    For horizontal g < .25, vertical load is 0
    For .25 < horizontal g < .5, vertical load is .5 * horizontal load
    For . 5 < horizontal g < .75, vertical load is equal to the horizontal load
    For 1.0 < horizontal g < 2.0, vertical load is 2 * horizontal load
    For horizontal g > 2.0, vertical load is 4 * horizontal load

For general guidance, when restraint is required with this code, FHS and FLSS isolators as well as ¼" restraint cables will 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). 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 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 ½".

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.

Current maps applicable to either specification can be quite detailed and unreadable in a small scale. To resolve this, dynamic Maps can be downloaded from the following websites: http://geohazards.cr.usgs.gov/eq/design/ibc/IBC1615-1us.pdf or short period acceleration (S_s) and http://geohazards.cr.usgs.gov/eq/design/ibc/IBC1615-2us.pdf for long period acceleration (S_1). 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.

It must be noted that the maps indicate the Maximum Spectral Response for long and short periods (S_S & S_l) and not the Design Spectral Response. The ground accelerations used for the design of Architectural and Equipment's attachment are the short period (.2 second) values only (S_S). These are multiplied by the site (soil) Classification Factor (F_a) from table 1615.1.2(1) and then multiplied 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 ¾. This, the **Design Spectral Response at Short Periods** or S_{DS} is the final acceleration coefficient used in the design. The Site Factors for various soil types and mapped Acceleration Factors (S_S) are listed in the table below.

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**				
		$S_s \leq 0.25$	**$S_s = 0.50$**	**$S_s = 0.75$**	**$S_s = 1.0$**	**$S_s \geq 1.25$**
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 an in cases where Site Class E or F are not expected, Site Class D shall be assumed.

A similar Table exists for Long Period Response S_{D1}. It is computed in the same manner (2/3 S_1 x F_v). For our purposes, this is a second screen that must be met to exempt a project from the need to perform a seismic analysis. The table is shown below.

Site Factor (F_v) Based on Site Class and Mapped Spectral Response for Long Periods (S_1)[a]						
Site Class	**Soil Type**	**Mapped Spectral Response Accel at Short Periods**				
		$S_s \leq 0.1$	**$S_s = 0.2$**	**$S_s = 0.3$**	**$S_s = 0.4$**	**$S_s \geq 0.5$**
A	Hard Rock	0.8	0.8	0.8	0.8	0.8
B	Moderate Rock	1.0	1.0	1.0	1.0	1.0
C	Dense Soil, Soft Rock	1.7	1.6	1.5	1.4	1.3
D[c]	**Stiff Soil**	**2.4**	**2.0**	**1.8**	**1.6**	**1.5**
E	Soft Soil, Clay	3.5	3.2	2.8	2.4	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 an in cases where Site Class E or F are not expected, Site Class D shall be assumed.

Levels of Seismic Concern are identified in the new code as "**Seismic Design Category**". These are a function of the structure's end use and the ground acceleration coefficient. A rough definition of the 3 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. Below are 2 Tables from the code indicating the Seismic Design Categories for various conditions. The Seismic Design Category appropriate for a project is the highest letter value obtained from the 2 tables below.

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

[a] S_1 is Mapped Max Considered Spectral Response

Seismic Design Category based on 1.0 Second Response Accelerations			
	Seismic Use Group		
S_{D1} Value	I	II	III
$S_{D1} < 0.067g$	A	A	A
$0.067g \leq S_{D1} < 0.133g$	B	B	C
$0.133 \leq S_{D1} < 0.20g$	C	C	D
$0.20g \leq S_{D1}$	D	D	D
$0.75g \leq S_1$[a]	E	E	F

[a] S_1 is Mapped Max Considered Spectral Response

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 2 levels of 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 Earthquake
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.

In the case of the **2000 IBC**, the occasions when it is not necessary to have seismic restraint are:

Entire Structures (and contents) that are exempted from Seismic review are:

1) Group R-3, Single family stand alone residential structures not more than 3 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 Arch Elements exempted from Seismic review are:

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 is1.0
3) All architectural elements in structures that fall into Seismic Design Category C and where the Importance Factor is1.0, and there are fewer than 3 stories.

Specific Component exemptions for Mechanical/Electrical Equipment are:

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.
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 accumulative 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 accumulative 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 Design 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 3 times the operating weight.

Specific Component exemptions for Architectural Elements are:

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) All Partitions under 6 ft in height or Partitions under 9 ft in height with an equivalent Seismic load of less than 5 psf.

Other

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

In the case of the **TI 809-04** spec, the occasions when it is not necessary to have seismic restraint are considerably fewer. There are no exemptions for entire structures or general equipment types and there are only a few for specific components as follows:

Specific Component exemptions for Mechanical Equipment are:

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 basic Design Force Equation (g’s) used in both the **2000 IBC** and **TI 809-04** is:

$$F_p = ((0.4a_pS_{DS}) / (R_p / I_p))(1 + 2z / h)$$

Where:
F_p is the Horizontal Design Seismic Load
a_p is the component amplification factor drawn from the Component Coefficient Table
S_{DS} is the design spectral response at short periods as previously determined.
R_p is the Component response modification factor drawn from the Component Coefficient Table below
I_p is the component importance factor as previously determined.
z is the component elevation above grade in the building or structure
h is the average roof height of the structure above grade.

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

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.

Although the above is the prime equation used to determine the design force, the code also contains a maximum and minimum screen value that must be checked. The maximum design limit is:

$$F_p = 1.6\ S_{DS}\ I_p$$

And the minimum design limit is:

$$F_p = 0.3\ S_{DS}\ I_p$$

Vertical Force Component

For our purposes, it can be assumed that a vertical force component must be factored into the restraint analysis. Its value would be:

$$F_{pv} = 0.2\ S_{DS}$$

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, he outputted forces from the above equations are working strength based figures. Because of this, it 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 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 Rp (where Rp 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

<u>Consolidating the above into simple understandable equations, we get the following:</u>

Using the previously determined design force F_p, steel and bolt and fastener allowables as per LFR, 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):

Shallow embed anchors (< 8 dias)

Lateral Design Load = 1.95 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 1.95 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3

Standard embed anchors (>= 8 dias)

Lateral Design Load = 1.3 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 1.3 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3

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

Standard embed anchors (>= 8 dias)

Lateral Design Load = 1.3 x F_p/ 1.4
Vertical Design Load = 1.3 x F_{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 Anchor Allowables by 1.6
   Vertical Design Load = F_{pv}/ 1.4, but increase Anchor Allowables by 1.6

5) Isolated Equipment Connection via Through Bolts using the ASD Bolt Allowables:
   Lateral Design Load = 2 x F_p / 1.4, but increase Bolt Allowables by multiplying by 4/3
   Vertical Design Load = 2 x F_{pv}/ 1.4, but increase Bolt Allowables by multiplying by 4/3

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

Shallow embed anchors (< 8 dias)

Lateral Design Load = 3.9 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 3.9 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3

Standard embed anchors (>= 8 dias)

Lateral Design Load = 2.6 x F_p/ 1.4, but increase Anchor Allowables by multiplying by 4/3
Vertical Design Load = 2.6 x F_{pv}/ 1.4, but increase Anchor Allowables by multiplying by 4/3

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

Standard embed anchors (>= 8 dias)

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

8) Isolated Equipment Connection to wood with Lag Screws as rated per ASD:
Lateral Design Load = 2 x F_p/ 1.4, but increase Anchor Allowables by 1.6
Vertical Design Load = 2 x F_{pv}/ 1.4, but increase Anchor Allowables by 1.6

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 ¼" restraint cables will work for "at grade" applications in lower level (below 1 g) 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). 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 ½".

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.