Vibration Isolation and Seismic Control
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UNDERSTANDING THE IBC (INTERNATIONAL BUILDING CODE)

(Architectural Components and Equipment Restraint)

The intent of this document is to offer some simplified guidance to understanding the above code and how it applies to nonstructural components. Significantly more detailed information is provided in the code itself. Before applying the information in this document, the code should be reviewed for further clarification on many of the details that are presented here in general terms.

Section 1
General Information

All of the generations of the IBC use as a basis of design ASCE7 (American Society of Civil Engineers, Minimum Design Loads for Buildings and other Structures). As new versions of ASCE7 are released, these are generally picked up by the next released version of the IBC. In some cases, there is a 1 to 1 relationship between the two, but not always. The table below indicates the relationship between the IBC codes (by year of issue) and their ASCE counterparts.

IBC – ASCE7 Relationship

INTERNATIONAL BUILDING CODE YEAR (IBC)	ASCE7 VERSION	ASCE7 SEISMIC NONSTRUCTURAL COMPONENTS CHAPTER	ASCE7 WIND CHAPTER
2000	98	9	6
2003	02	9	6
2006	05	13	6
2009	05	13	6
2012	10	13	29

Note: for IBC 2012 there is a special section in Chapter 29 relating to mechanical components. It is "WIND LOADS ON OTHER STRUCTURES AND BUILDING APPURTENANCES—MWFRS". Chapter 30 "WIND LOADS – COMPONENTS AND CLADDING" is not the appropriate chapter to reference.

The 2000 IBC code is no longer used on new projects within the United States and will not be addressed in this document beyond this brief history. The 2003 and 2006 version are for the most part being phased out leaving the 2009 as being the most prevalent with the 2012 being adopted as each state updates their standards of practice.

In looking at the above table, you will see that the 2006 IBC and 2009 IBC are both based on the same version of ASCE7 (05) as the next version of ASCE7 was not released until 2010. This makes the two nearly identical, and as such, they will be referenced in this document as 2006/2009 IBC. The latest version of the IBC (2012) is substantially different from the previous versions, particularly in respect to the attachment of components to concrete.

It is critical for the designer of the restraint system(s) (for both wind and seismic load conditions) to be familiar with the above documents and to the reference documents that they cite.

Section 2
Coordination

The selection and installation of the proper seismic restraints for non-structural components require good coordination with the design professionals and contractors involved with the building project. A good spirit of cooperation and coordination is especially required for projects that have been designated as essential facilities, such as hospitals, emergency response centers, police and fire stations. Coordination between the various design professionals and contractors will be a constant theme throughout this section. This coordination is vital for the following reasons.

1) The space required for the restraint of components can be considerably more than would be necessary if seismic concerns are not an issue. This can impact the layout of mechanical rooms.
2) The forces being carried by the restraint components can be significant requiring heavier slabs, extra reinforcement, doweling, etc., where attachment to concrete is required.
3) Relative positioning of critical versus non-critical systems can impact the design of distribution systems.
4) Confined areas can make it extremely difficult, if not impossible to incorporate cost effective restraint arrangements.

Because the seismic or wind forces that can be imparted into the building structure can far overshadow typical gravity loads, the impact on the structure at the structural attachment points must be reviewed and approved by the structural engineer of record.

Section 3
Determining the Baseline Ground Acceleration and Seismic Design Category

As with any design job, there is certain basic information that is required before seismic restraints can be selected and placed. The building owner, architect, and structural engineer make the decisions that form the basis for the information required to select the seismic restraints for all of the mechanical and electrical systems in the building. This information should be included in the specification and bid package for the project. It also should appear on the first sheet of the structural drawings.

Ground Acceleration

The first bit of information required is the mapped ground motion. If not provided in the project documents, it can be found on a seismic hazard map. All of the versions of the ASCE7 are based on seismic maps that have been generated by USGS (United States Geological Survey). The early codes use 1996/2002 maps. The current codes use maps created in 2008 and later. There are several maps that show ground motions based on different probability levels. Those of interest are the ones listing 2% chance of exceedance over a 50 year period. There are 2 maps of this type, those showing S_s (short period motion) and those showing S_1 (long period motion). Both are needed for the proper selection of restraint components. Many maps, both domestic and international are available through the USGS website.

Building Use

How a building is to be used greatly affects the level of seismic restraint that is required for non-structural components. In the 2000/2003 IBC the level of risk assigned to a structure was determined in a cumbersome 3 step process. First building "Use" groups were assigned and these were then converted to "Occupancy Categories" which in turn were grouped into "Risk Categories". For the 2006/2009 IBC, this process was simplified to allow the level of risk assigned to a structure to be determined in a 2 step process. First the nature of the occupancy (building use) was quantified and broken into groups identified as "Occupancy Categories", the risk for the various "Occupancy Categories" was assessed and a "Risk Category" assigned. In the 2012 IBC, this was consolidated further into a single step process wherein the

Use/Occupancy groups link directly to the "Risk Category". "Risk Categories" range from I to IV as they always have and as indicated in the table below.

The table below has been compiled from Table 1-1 and 9.1.3 of ASCE7-98/02, Table 1-1 of ASCE7-05, and Table 1.5-1 of ASCE7-10, and ties the Seismic Use Group, Occupancy Category and Risk Categories together. The nature of the building use is determined by the building owner and the architect of record.

Seismic Use Group/Occupancy and Risk Categories

SEISMIC USE GROUP 2000/2003 IBC	OCCUPANCY CATEGORY 2006/2009 IBC	RISK CATEGORY 2012 IBC	BUILDING USE
I	I	I	Buildings and other structures whose failures would pose a significant risk to human life.
	II	II	Buildings and other structures not listed in Occupancy/Risk Categories I, III, and IV or Seismic Use Groups II and III.
II	III	III	Buildings and other structures whose failure would pose a significant risk to human life, cause a significant economic impact, or cause mass disruption in the day-to-day life of civilians.
III	IV	IV	Buildings or other structures that are essential for post disaster recovery, whose failure would pose a substantial hazard to the community, or are used to process, store, or dispose of hazardous materials.

Site Class

The site class is related to the type of soil and rock strata that directly underlies the building site. Site classes range from A to F progressing from the stiffest to the softest strata. The table below lists the various site classes and their corresponding strata.

Generally the structural engineer is responsible for determining the site class for a project. If the structural engineer's firm does not have a geotechnical engineer on staff, this job will be contracted to a geotechnical firm. The site class is determined in accordance with the references stated above from ASCE7-98/02, ASCE7-05, and ASCE7-10. The site profile is normally obtained by drilling several cores on the property. If there is insufficient information concerning the soil properties, then the IBC indicates that the default site class D should be assigned to the project.

Site Class

SITE CLASS	SOIL TYPE
A	Hard Rock
B	Rock
C	Very Dense Soil & Soft Rock
D	Stiff Soil (Default Site Class)
E	Soft Clay Soil
F	Liquefiable Soils, Quick Highly Sensitive Clays, Collapsible Weakly Cemented Soils, etc. These require site response analysis.

Ground Level Design Forces (S_{DS}, S_{D1})

In order to determine the magnitude of the seismic forces used on a particular project, the mapped acceleration as well as the soil type information must be factored together. Both the short and long period motions need to be considered. This is done using the following two tables.

Short Period Ground Acceleration Factor

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.

Long Period Ground Acceleration Factor

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.

To use these tables, the ground motion parameters at the jobsite (S_s and S_1) are linked to the soil site class and appropriate multipliers (F_a and F_v) are read off the tables. These multipliers are then applied to the S_s and S_1 terms to compute appropriate peak forces (both long and short period) for the structure's location. Note that the interpolation of these factors with respect to the actual amplitude of the ground motion at the jobsite is both possible and recommended.

The final factor that is used to determine the "design" loads is a factor of 2/3. This factor is introduced to reduce the "maximum considered earthquake" loads at a given location to a more reasonable design level. This reflects the fact that unlike many other natural events, high magnitude earthquakes occur very rarely and as such, designing for events of this magnitude is not practical for most conventional structures. It should however be noted that for critical structures such as hospitals, a high value importance factor brings the loads back up to the full "maximum considered earthquake" level.

Thus the design forces at grade become:

$$\boldsymbol{S_{DS} = \frac{2}{3} F_a S_S}$$

and

$$S_{D1} = \frac{2}{3} F_v S_1$$

<u>Seismic Design Category</u>

Once the S_{DS} and S_{D1} levels are determined, it is possible to determine the *Seismic Design Category*. This essentially establishes levels of seismic concern for various building types and locations and is of great importance to everyone involved with non-structural components. The

Seismic Design Category to which a building has been assigned will determine whether seismic restraints are required or not, and if they qualify for exemption, which non-structural components may be exempted, and which will need to have seismic restraints selected and installed.

There are six Seismic Design Categories, A, B, C, D, E, and F. The level of restraint required increases from Seismic Design Category A through F. The Seismic Design Category to which a building or structure is assigned is determined through the use of the short (S_{DS}) and long (S_{D1}) period tables below. The worst case will determine the Seismic Design Category.

Seismic Design Category

VALUE OF S_{DS}	OCCUPANCY/RISK		
	I or II	III	IV
$S_{DS} < 0.167$	A	A	A
$0.167 \le S_{DS} < 0.33$	B	B	C
$0.33 \le S_{DS} < 0.50$	C	C	D
$0.50 \le S_{DS}$	D	D	D

VALUE OF S_{D1}	OCCUPANCY/RISK		
	I or II	III	IV
$S_{D1} < 0.067$	A	A	A
$0.067 \le S_{D1} < 0.133$	B	B	C
$0.133 \le S_{D1} < 0.20$	C	C	D
$0.20 \le S_{D1}$	D	D	D

Notes: For Occupancy/Risk Categories I, II, or III (Seismic Use Group I or II) structures, if the Mapped Spectral Response Acceleration Parameter is greater than or equal to 0.75, then the structure will be assigned to Seismic Design Category E. For Occupancy/Risk Category IV (Seismic Use Group III) structures, if the Mapped Spectral Response Acceleration Parameter is greater than or equal to 0.75, then the structure will be assigned to Seismic Design Category F.

To determine the appropriate Seismic Design Category, both the long (S_{D1}) and short (S_{DS}) forces must be considered. These are read off the left hand column.

The other variable is the Occupancy/Risk Category. A table summarizing the breakdown by building use was provided earlier in this document. These are selected along the top row.

To ensure consistency, the Seismic Design Category should be, but isn't always determined by the structural engineer of record.

If the table output results in different Seismic Design Categories, the worst case (highest letter value) must be used.

Section 4
Component Importance Factor

In codes predating the IBC, the *Importance Factor* was linked to the building use. It is now tied more closely to the use of the equipment rather than the use of the building. The designator for Importance with equipment is I_p and should not be confused with I_E, the building importance factor. As a result, it is now quite common to have high importance components in a low importance structure and vice versa. As far as equipment is concerned, there are 2 levels of importance only (I_p=1.0 and I_p=1.5). The equipment is either critical for life safety or it isn't. There is no in between as is the case with the building importance factor (I_E).

The component importance factor (I_p) 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 Seismic Use Group III or Risk Category IV.

All other conditions use an Importance Factor of 1.0.

Section 5
When do I *NOT* need to worry about Seismic Restraint?

The Code includes several layers of exclusions that identify instances in which the restraint of equipment need not be designed. These begin with entire structures, then move into areas where equipment only is excluded and then finally, listed by size and location, particular pieces of equipment or architectural elements that need not be reviewed under particular situations.

General Mechanical Components and Architectural Elements that need not be addressed:
1) All non-structural mechanical and electrical components in structures that fall into Seismic Design Category A or B. *(All IBC Codes)*

2) Architectural elements in Seismic Design Category B other than parapets supported by bearing or shear walls provided their importance factor = 1.0. *(All IBC Codes)*
3) All mechanical and electrical components in structures that fall into Seismic Design Category C and where the Importance Factor is 1.0. *(All IBC Codes)*
4) Mechanical and electrical components in all Seismic Design Categories where:
   a) The component Importance Factor is 1.0. *(All IBC Codes)*
   b) The component is positively attached to the structure. *(All IBC Codes)*
   c) Flexible connections are provided between the component and associated piping, ductwork and conduit. *(All IBC Codes)*
   d_1) And either the component weighs less than 400 lb and has a center of mass located 4 ft or less above the adjacent floor level or the component weighs less than 20 lb (mounted anywhere) or in the case of distribution systems, the system weighs less than 5 lb/ft. *(IBC 2012)*
   d_2) And either the component weighs less than 400 lb and is mounted at an elevation of 4 ft or less above the adjacent floor level or the component weighs less than 20 lb (mounted anywhere) or in the case of distribution systems, the system weighs less than 5 lb/ft. *(IBC 2003, 2006, 2009)*

<u>Specific Component Exemptions for Mechanical Equipment are:</u>

(Note: IBC 2012 allows no exemptions for I_p = 1.5 ducts of any size that cross seismic joints)

1) Trapezed ductwork where the total supported weight is less than 10 lb/ft and the duct does not carry toxic or flammable gases and is not used for smoke control. *(IBC 2012)*

2_1) All ductwork that is suspended on hangers 12" or less in length for the full length of a run equipped with non-moment generating connections to the structure and the duct does not carry toxic or flammable gases and is not used for smoke control (no matter what Seismic Design Category). *(IBC 2012)*

2_2) All ductwork that is suspended on hangers 12" or less in length for the full length of a run equipped with non-moment generating connections to the structure for all Importance Factors (no matter what Seismic Design Category). *(IBC 2009)*

2_3) All ductwork that is suspended on hangers 12" or less in length for the full length of a run equipped with non-moment generating connections to the structure and where the Importance Factor does not exceed 1.0 (no matter what Seismic Design Category). *(IBC 2003, 2006)*

3_1) All ductwork that is less than 6 sq ft in area or weighing 17 lb/ft and where the duct does not carry toxic or flammable gases and is not used for smoke control (no matter what Seismic Design Category) and where the motion induced by a seismic event will not result in contact with larger ducts or components or where protection is offered if contact is possible. *(IBC 2012)*

3_2) All Ductwork that is less than 6 sq ft in area or weighing 17 lb/ft for the full length of a run for all Importance Factors and the motion induced by a seismic event will not result in contact with other components. (Seismic Design Category C and higher) *(IBC 2009)*

3_3) All 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 (Seismic Design Category C and higher). *(IBC 2006), (Note: this is accepted in later versions of the IBC and typically by local Authorities for I_p = 1.5 as well)*

3_4) All Ductwork that is less than 6 sq ft in area where the Importance Factor does not exceed 1.0 (no matter what Seismic Design Category). *(IBC 2003), (Note: this is accepted by SMACNA 2nd Edition, later versions of the IBC and typically by local Authorities for I_p = 1.5 as well)*

4_1) Piping that is not plumbing or made of low deformability materials, is protected from impact with other non-structural components, is located in a Seismic Design Category C structure with an I_p of 1.5 and has a diameter of 2" or less. *(IBC 2012)*

4_2) High deformability piping that is protected from impact with other non-structural components, is located in a Seismic Design Category C structure with an I_p of 1.5 and has a diameter of 2" or less. *(IBC 2003, 2006, 2009)*

5_1) Piping that is not plumbing or made of low deformability materials, is protected from impact with other non-structural components, is located in a Seismic Design Category D, E or F structure with an I_p of 1.5 and has a diameter of 1" or less. *(IBC 2012)*

5_2) High deformability piping that is protected from impact with other non-structural components, is located in a Seismic Design Category D, E or F structure with an I_p of 1.5 and has a diameter of 1" or less. *(IBC 2003, 2006, 2009)*

6_1) Piping that is not plumbing or made of low deformability materials, is protected from impact with other non-structural components, is located in a Seismic Design Category D, E or F structure with an I_p of 1.0 and has a diameter of 3" or less. *(IBC 2012)*

6_2) High deformability piping that is protected from impact with other non-structural components, is located in a Seismic Design Category D, E or F structure with an I_p of 1.0 and has a diameter of 3" or less. *(IBC 2003, 2006, 2009)*

7) Trapezed piping whose total weight does not exceed 10 lb/ft and where each pipe conforms to 4_1, 5_1 and 6_1. *(by convention on older IBC codes, in print for IBC 2012)*

8) All piping that is suspended on hangers 12" or less in length for the full length of a run equipped with non-moment generating connections to the structure (no matter what Seismic Design Category). *(All IBC Codes)*

9_1) Light fixtures, signs and fans not connected to ducts or piping supported from above by chains or other non-moment generating connection, that have free reign to swing in a full 360 deg arc without contacting any other component or structure and have a supporting connection designed to take a simultaneous load equal to 1.4 times its weight acting both vertically and horizontally. *(IBC 2006, 2009, 2012)*

9_2) 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. *(IBC 2003)*

Specific Component Exemptions for Architectural Elements are:

1) Partitions under 9 ft in height with a linear weight not to exceed 10 lb/ft multiplied by the partition height and the lateral Seismic load does not exceed 5 psf. *(IBC 2006, 2009, 2012)*
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. *(IBC 2003)*

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 independent restraint system is required). *(All IBC Codes)*
2) The consequential damage that can result from a less important (critical) system failing and damaging a more important (critical) system, shall be considered and preventive steps shall be taken to ensure that this will not occur. *(All IBC Codes)*
3) All Electrical equipment and distribution systems that have an Importance Factor of 1.0 *(All IBC Codes)*
4) Conduit that has a diameter of 2.5" (Trade Size) or less and an Importance Factor of 1.5. *(IBC 2006, 2009, 2012)*

5_1) Trapeze mounted raceways, bus ducts, cable trays and conduit that weigh less than 10 lb/ft and an Importance Factor of 1.5. *(IBC 2006, 2009)*

5_2) Trapeze mounted raceways that weigh less than 10 lb/ft. *(IBC 2012)*

6) All raceways that are suspended on hangers 12" or less in length for the full length of a run equipped with non-moment generating connections to the structure (Seismic Design Category C and higher). *(All IBC Codes)*

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Section 6
Computing the Appropriate Seismic Design Force

The basic Design Force Equation used in all versions of the IBC is:

$$F_P = \frac{0.4 a_P S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)}\left(1 + 2\frac{z}{h}\right)$$

Where:

F_p is the Horizontal Design Seismic Load
a_p is the component amplification factor drawn from the Component Coefficient Table for the appropriate IBC code below
S_{DS} is the design spectral response at short periods as previously determined in Section 3
W_p is the component operating weight
R_p is the Component response modification factor drawn from the Component Coefficient Table for the appropriate IBC code below
I_p is the component importance factor as previously determined in Section 4
z is the component elevation above grade in the building or structure
h is the average roof height of the structure above grade

The 0.4 factor was introduced as a modifier in recognition of the fact that the MEP components inside the building would react more strongly to the long period earthquake ground motion than to the short period motion. The 0.4 factor brings the design level acceleration for the MEP components more in line with the design level acceleration that is applied to the building structure itself.

ASCE7-98/02, -05, and -10 also define an upper and lower boundary for the horizontal force that is to be applied to the center of gravity of a component. The horizontal seismic force acting on an MEP component is not required to be greater than:

$$F_P = 1.6 S_{DS} I_P W_P$$

And the horizontal seismic force acting on an MEP component is not to be less than:

$$F_P = 0.3S_{DS}I_PW_P$$

The $\left(1+2\frac{z}{h}\right)$ term is recognition of the fact that all buildings and structures become more flexible as they increase in height. That is they are much stiffer and stronger at the foundation level than at the roof. Since the ground motion from an earthquake enters the building structure at the foundation level, the actual accelerations imparted to an MEP component will be greater the higher in the building they are attached. A building may be likened to a large tuning fork that is being shaken at the bottom. It is a vibrating system that will have a certain natural period that is, in a general fashion, based on its mass and stiffness. If the natural period of the building is at, or close to, the earthquake period, the motion of the building could be extreme.

The horizontal seismic design force must be applied to the component along its least resistant axis. This is likely not one of the primary axes. The horizontal seismic design force must also be applied in conjunction with all of the expected dead loads and service loads. The idea here is that the horizontal seismic design force is to be applied in the direction that causes the highest stress in the supports and restraints, and thus produces the most conservative results. Load combination equations are provided in the various versions of the IBC that indicate all of the various load considerations that must be addressed.

The MEP (Mechanical Equipment and Pipe) component, its supports, and its restraints must also be designed for a vertical seismic design force that acts concurrently with the horizontal seismic design force. This vertical seismic design force must be directed such that it also produces the highest stress in the supports and restraints, thus producing the most conservative result. This vertical seismic design force is defined as follows:

$$F_V = \pm 0.2S_{DS}W_P$$

a_p and R_p Factors

The a_p and R_p factors represent, respectively, the dynamic response of the attachment method and the durability level of the restrained piece of equipment. The component amplification factor (a_p) increases the seismic force for conditions where looseness in the mounting system can create pounding or where the attachment can possibly resonate with the motion generated by a seismic event. This number will increase as the attachment becomes more resilient.

The component response modification factor (R_p) is a measure of how much energy the restrained component along with its supports and attachments can absorb without sustaining crippling damage. A common term used throughout the HVAC industry for this factor is the fragility level. For R_p = 1.0 the component is extremely fragile. For R_p = 12.0, on the other hand, the component would be very robust.

The values for a_p and R_p are assigned by the ASCE7 committee based on accumulated experience throughout the building industry. The evolution of these factors may be traced through the various tables that follow which represent 2003 IBC, 2006/2009 IBC and 2012 IBC.

2003 IBC a_p and R_p Values

MECHANICAL & ELECTRICAL COMPONENT[1]	a_p[2]	R_p
General Mechanical Equipment	-----	-----
Boilers and furnaces.	1.0	2.5
Pressure vessels on skirts and free standing.	2.5	2.5
Stacks and cantilevered chimneys.	2.5	2.5
Other	1.0	2.5
Piping Systems	-----	-----
High deformability elements and attachments (welded steel pipe & brazed copper pipe).	1.0	3.5
Limited deformability elements and attachments (steel pipe with screwed connections, no hub connections, and Victaulic type connections).	1.0	2.5
Low deformability elements and attachments (iron pipe with screwed connections, and glass lined pipe).	1.0	1.5
HVAC Systems	-----	-----
Vibration isolated.	2.5	2.5
Non-vibration isolated.	1.0	2.5
Mounted-in-line with ductwork.	1.0	2.5
Other	1.0	2.5
General Electrical	-----	-----
Distribution systems (bus ducts, conduit, and cable trays).	2.5	5.0
Equipment.	1.0	2.5
Lighting fixtures.	1.0	1.5

[1] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

[2] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P = 1.0 is to be applied to equipment that is rigid or rigidly attached. A value of a_P = 2.5 is to be applied to equipment regarded as flexible or flexibly attached.

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 overrides the value identified in the Component Coefficient table.

Beginning with the 2006 and 2009 versions of the IBC, a factor was introduced that over the long haul was intended to add an additional level of conservatism to components that are anchored to concrete and in which the expected mode of failure is in the concrete itself rather than in the steel portion of the anchor. Unfortunately, this factor was introduced in a clumsy fashion with the words in the code not following the actual intent. By the time the 2012 IBC passed through a couple of errata changes, the intent has been made fairly clear. There will be more on that version of the code in the following section.

Beginning with the 2006 IBC, Section 1908.1.16 has actually modified the verbiage in the ACI 318-05 document that is referenced to indicate that if a brittle concrete failure is expected, the "design strength" of the anchors must be increased by a factor of 2.5. This requires that over the course of the anchorage analysis, the mode of failure needs to be tracked as well as the failure limit capacity. The typical modes of failures for concrete anchors are steel failure in shear, steel failure in tension, concrete pullout in tension, concrete breakout in tension, concrete blow out in shear and concrete breakout in shear. As long as the steel failures govern, the 2.5 design strength of the anchor need not be applied.

Both the 2006 and 2009 IBC refer to ASCE7-05 which also includes a provision that anchors be sized for loads of 1.3 times the actual design loads. If however, the 2.5 factor is included, it over-rides the 1.3 factor and the two factors need not be applied simultaneously.

It should be noted in the case of 2006 IBC, the strength reduction factor is applied to the anchor capacity. This produces markedly different results than if the factor were to be applied to the load (which will become the case in the 2012 code).

Note also that these higher loads do not apply to through bolted connections, welds or to the strength of the restraint component itself. They need only be applied to the anchorage, and only then, if to concrete.

In the 2009 IBC, verbiage was introduced that effectively nullified the need to consider this extra 2.5 factor when working with the anchorage of equipment and other non-structural components. The 1.3 factor from ASCE7-05 then becomes the appropriate multiplier for use in an analysis.

While this is actually what happened with the 2009 IBC, it was unintentional and subsequently, with the introduction of the 2012 IBC and ASCE7-10, the codes were again re-written (albeit in a clumsy fashion again) to include the 2.5 factor. The initial release of the latest code cited a bunch of cross references that did not link together and subsequently an errata was issued both requiring a 2.5 factor in the case of brittle concrete failures, but also applying it to the load side of the equation rather than to the capacity side. This is the Ω_0 factor.

Vibration Isolation and Seismic Control
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2006/2009 IBC a_p and R_p Values

MECHANICAL AND ELECTRICAL COMPONENTS	a_p [1]	R_p [2]
Air-side HVAC – fans, air handlers and other mechanical components with sheet metal framing.	2.5	6.0
Wet-side HVAC – boilers, chillers and other mechanical components constructed of ductile materials.	1.0	2.5
Engines, turbines, pumps, compressors and pressure vessels not supported on skirts	1.0	2.5
Skirt supported pressure vessels.	2.5	2.5
Generators, batteries, transformers, motors and other electrical components made of ductile materials.	1.0	2.5
Motor control cabinets, switchgear and other components constructed of sheet metal framing.	2.5	6.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	2.5	3.0
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical and electrical components.	1.0	1.5
Vibration Isolated Components & Systems	-----	-----
Components and systems isolated using neoprene elements & neoprene isolated floors with elastomeric snubbers or resilient perimeter stops.	2.5	2.5
Spring isolated components and systems and vibration isolated floors closely restrained with elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components or systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices & suspended internally isolated components.	2.5	2.5
Distribution Systems	-----	-----
Piping in accordance with ASME B31. This includes in-line components with joints made by welding or brazing.	2.5	12.0
Piping in accordance with ASME B31. This includes in-line components constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0

Distribution Systems (cont)	-----	-----
Piping and tubing that is not in accordance with ASME B31. This includes in-line components constructed with high deformability materials with joints made by welding or brazing.	2.5	9.0
Piping and tubing that is not in accordance with ASME B31. This includes in-line components constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5
Piping and tubing of low deformability materials, such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials, with joints made by means other than welding or brazing.	2.5	6.0
Duct work constructed of low deformability materials such as cast iron, glass, or non-ductile plastics.	2.5	3.0
Electrical conduit, bus ducts, rigidly mounted cable trays and plumbing.	1.0	2.5
Suspended cable trays.	2.5	6.0

[1] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of a_P = 1.0 is to be applied to components that are rigid or rigidly attached. A value of a_P = 2.5 is to be applied to components regarded as flexible or flexibly attached.

[2] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

Ω_0 Factor

In the 2012 IBC a new factor is being introduced. It is Ω_0, otherwise known as the Overstrength factor. This is an added factor that is applied to the horizontal seismic force when evaluating anchorage connections to concrete. It is applied if the failure mode is determined to result from a brittle failure in the concrete itself. If the mode of failure is a ductile failure in the anchor itself or if the anchorage is not to concrete, this factor should be set to 1.0.

2012 IBC a_p, R_p and Ω_0 Values

MECHANICAL AND ELECTRICAL COMPONENTS	a_p [1]	R_p [2]	Ω_0 [3]
Air-side HVAC – fans, air handlers, and other mechanical components with sheet metal framing.	2.5	6.0	2.5
Wet-side HVAC – boilers, chillers, and other mechanical components constructed of ductile materials.	1.0	2.5	2.5
Engines, turbines, pumps compressors, and pressure vessels not supported on skirts.	1.0	2.5	2.5
Skirt supported pressure vessels.	2.5	2.5	2.5
Generators, batteries, transformers, motors, and other electrical components made of ductile materials.	1.0	2.5	2.5
Motor control cabinets, switchgear, and other components constructed of sheet metal framing.	2.5	6.0	2.5
Communication equipment, computers, instrumentation and controls.	1.0	2.5	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	2.5	3.0	2.5
Roof-mounted chimneys, stacks, cooling and electrical towers braced below their C.G.	1.0	2.5	2.5
Lighting fixtures.	1.0	1.5	1.5
Other mechanical and electrical components.	1.0	1.5	1.5
Vibration Isolated Components & Systems	-----	-----	----
Components and systems isolated using neoprene elements and neoprene isolated floors with elastomeric snubbers or resilient perimeter stops.	2.5	2.5	2.5
Spring isolated components and systems and vibration isolated floors closely restrained with elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0	2.5
Internally isolated components or systems.	2.5	2.0	2.5
Suspended vibration isolated equipment including in-line duct devices and suspended internally isolated components.	2.5	2.5	2.5

Distribution Systems	-----	-----	2.5
Piping in accordance with ASME B31. This includes in-line components, with joints made by welding or brazing.	2.5	12.0	2.5
Piping in accordance with ASME B31. This includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0	2.5
Piping and tubing that is not in accordance with ASME B31. This includes in-line components, constructed with high deformability materials with joints made by welding or brazing.	2.5	9.0	2.5
Piping and tubing that is not in accordance with ASME B31. This includes in-line components, constructed of high or limited deformability materials with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	4.5	2.5
Piping and tubing of low deformability materials, such as cast iron, glass, or non-ductile plastics.	2.5	3.0	2.5
Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0	2.5
Ductwork, including in-line components, constructed of high or limited deformability materials, with joints made by means other than welding or brazing.	2.5	6.0	2.5
Duct work constructed of low deformability materials such as cast iron, glass, or non-ductile plastics.	2.5	3.0	2.5
Electrical conduit and cable trays.	2.5	6.0	2.5
Bus ducts.	1.0	2.5	2.5
Plumbing.	1.0	2.5	2.5

[1] The value for a_P shall not be less than 1.0. Lower values shall not be used unless justified by a detailed dynamic analysis. A value of $a_P = 1.0$ is to be applied to components that are rigid or rigidly attached. A value of $a_P = 2.5$ is to be applied to components regarded as flexible or flexibly attached.

[2] Components mounted on vibration isolators shall be restrained in each horizontal direction with bumpers or snubbers. If the maximum bumper/snubber clearance, or air gap, is greater than 1/4 in., the horizontal seismic design force shall be equal to $2F_P$. If the maximum bumper/snubber clearance, air gap, is less than or equal to 1/4 in., the horizontal seismic design force shall be taken as F_P.

[3] Over-strength Factor (This is to be applied to horizontal Seismic load for anchorage to concrete). Applicable if the mode of failure at the anchor is due to a brittle failure of the concrete.

Section 7
Wind Loads

Unlike seismic loads, wind loads increase with the size of a component rather than its weight. Since the unit weight helps it to be able to resist wind loads, for equipment that has a weight that can vary it is not uncommon that the worst case load conditions to occur when the equipment weighs less rather than when it weighs more.

In a similar fashion to seismic loads, the baseline wind forces generally come from a map and these are then tailored by the local conditions, the elevation in a structure and the relative criticality of that structure. A significant difference between a wind and a seismic analysis also has to do with the attachment and durability factors (critical for seismic, but meaningless for wind) Instead, the shape of the equipment itself as well as its size relative to that of the structure on which it sits becomes important.

Lastly, unlike seismic restraint, there are no exemptions for components that are mounted outside or on top of a structure. Even shielding, such as barrier walls or screens, does not decrease the forces that must be considered when reviewing an application.

The table below indicates the design categories for applications based on wind. Although similar to the table for Seismic, it is not identical.

Building, Occupancy and Risk Category for Wind

BUILDING CATEGORY 2003 IBC	OCCUPANCY CATEGORY 2006/2009 IBC	RISK CATEGORY 2012 IBC	BUILDING USE
I	I	I	Buildings and other structures whose failures would pose a significant risk to human life.
II	II	II	Buildings and other structures not listed in Occupancy/Risk Categories I, III, and IV or Seismic Use Groups II and III.
III	III	III	Buildings and other structures whose failure would pose a significant risk to human life, cause a significant economic impact, or cause mass disruption in the day-to-day life of civilians.

IV	IV	IV	Buildings or other structures that are essential for post disaster recovery, whose failure would pose a substantial hazard to the community, or are used to process, store, or dispose of hazardous materials.

Additional input that is required when computing the design loads for wind applications is the Wind Importance Factor. These also are not consistent with the Seismic Importance Factors and have to be considered separately. The Occupancy/Risk category defined in the table above is used in conjunction with geographical factors to define the Wind Importance Factor. For the 2003 through 2009 IBC codes (ASCE7-02 and ASCE7-05), the Importance Factor is simply a multiplier that can be drawn from the table below.

In the case of the 2012 IBC, there are separate maps for Risk Category I/II and Risk Category III/IV. No attempt is being made to reproduce the maps in this document and instead all versions (for all of the involved codes), should be sourced through ASCE.

ASCE7-02/-05 Wind Importance Factor

BUILDING, OCCUPANCY, OR RISK CATEGORY	NON-HURRICANE PRONE REGIONS AND HURRICANE PRONE REGIONS WITH $V = 85 - 100\ mph$ AND ALASKA	HURRICANE PRONE REGIONS WITH $V > 100\ mph$
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV	1.15	1.15

The next factor required for a wind analysis is the Exposure Category. The Exposure Category takes into account the surrounding terrain and structures and is generally assigned to the building by the structural engineer. It is typically listed on the first sheet of the structural drawings. The following table (common to all versions of the IBC) will help with understanding the assignment of the Exposure Category.

ASCE7-02/-05 Wind Exposure Category

BUILDING, OCCUPANCY, OR RISK CATEGORY	SURROUNDING TERRAIN & STRUCTURES
B	Urban and Suburban areas, wooded areas, or other terrain with many closely spaced obstructions of single family dwelling size or larger.
C	Open terrain with scattered obstructions generally 30 ft or less in height; including flat open country, grasslands, and all water surfaces in hurricane-prone regions.
D	Flat unobstructed areas and water surfaces outside hurricane-prone regions; includes smooth mud flats, salt flats, and unbroken ice.

(Note: Wind Exposure Category A was eliminated beginning with ASCE7-02)

Like the Seismic Forces, the Wind Forces vary with the height of the structure. Unlike the Seismic Forces, this increase is not based on the relationship between the elevation of the component and the overall height of the structure but instead is purely based on the elevation above the plane of the soil at the base of the structure. Generally these forces increase with elevation.

The basic wind load equation for IBC 2003, 2006 and 2009 is:

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I$$

Where

$\boldsymbol{q_z}$ = the velocity pressure at height $\boldsymbol{z}$ of the centroid of the area being impacted (psf). In this section it will be evaluated at the mean roof height of the building, and $\boldsymbol{z}$ will be taken to be the mean roof height at the equipment mounting location.
$\boldsymbol{K_z}$ = the velocity pressure exposure coefficient.
$\boldsymbol{K_{zt}}$ = the topographic factor.
$\boldsymbol{K_d}$ = the wind directionality factor.
$\boldsymbol{V}$ = the Design Wind Speed.
$\boldsymbol{I}$ = the Wind Importance Factor.

The basic wind load equation for IBC 2010 is the same except the Importance factor has been removed.

$$q_z = 0.00256 K_z K_{zt} K_d V^2$$

Computing Variable Values

K_z The velocity pressure exposure coefficient is defined in Tables 6-3 and 6-2 of ASCE7-02/-05, and Tables 29.3-1 and 26.9-1 of ASCE7-10. For the purposes of this analysis the equations listed in Note 1 of the tables will be used to compute the values for K_{zt} rather than trying to use tabulated data. The equation used in this section will be:

$$K_z = 2.01\left(\frac{z}{z_g}\right)^{\frac{2}{\alpha}} \text{ Where } 15 \le z \le z_g$$

Where:

z = the mean roof height of the building at the equipment mounting location (ft) and $z = 15$ for mean roof heights less than 15 ft.

The constants z_g and α are defined in Table 6-4 of ASCE7-98, Table 6-2 of ASCE7-02/-05, and Table 26.9-1 of ASCE7-10 and are repeated below in Table D2.2.3-1 for convenience.

Constants by Exposure Category for Computing K_z

EXPOSURE CATEGORY	α	z_g (FT)
B	7.0	1200
C	9.5	900
D	11.5	700

K_{zt} The topographic factor, accounts for the wind speed-up effect that occurs when wind flows over a hill or an escarpment. It is defined by Equation 6-3 and Figure 6-4 of ASCE7-02/-05, and Equation 26.8-1 and Table 26.8-1 of ASCE7-10. The values are the same over all four versions of ASCE7. Since often the exact topographic conditions surrounding a building site unknown, a reasonable factor to use to get an estimate of the design wind loads will be to assume it equal to 1. This should, however, be validated before a final assessment is made.

K_d The wind directionality factor accounts for how the wind strikes the object, whether the wind can strike the object from only one direction, or whether it can strike the object from any direction. It allows for a reduction in the magnitude of the design wind loads to account for the reduced probability that the highest winds will strike the equipment from the worst possible direction. The values for this factor are given in Table 6-6 of ASCE7-02, Table 6-4 of ASCE7-05, and Table 26.6-1 of ASCE7-10. Timothy Reinhold in his ASHRAE Journal paper "Wind Loads and Anchorage Requirements for Rooftop Equipment" (see Section D2.2.1 of this manual for the reference) recommends that the Wind Directionality Factor be given the following value for rooftop equipment:

$$K_d = 0.85$$

This is the value given in the ASCE7 tables listed above that is applied most frequently to objects that can be struck by the wind from any direction. This means that equipment is part of the main wind force resisting system (MWFRS) and is not considered to be components and cladding.

V The Design Wind Speed is drawn from the appropriate maps presented in the code documents. No attempt is being made to reproduce that information here.

Wind Force Computation for IBC 2003 (ASCE7-02):

The equation for the design wind load for ASCE7-02 is found in Section 6.5.13 which is titled "Design Wind Loads on Open Buildings and Other Structures". It is identified as equation 6-25.

$$F = q_z G C_f A_f$$

Where:

F = the horizontal design wind load (lbs).

G = the gust effect factor.

C_f = the net force coefficient.

A_f = the projected area normal to the wind (ft^2).

For the purposes of this document it will be more convenient to express the design wind load as a design wind pressure. In this way this document will be more generically applicable. So, then Equation D2.2.3-4 will have the following form:

$$p_h = q_z G C_f$$

Where:

p_h = the horizontal design wind pressure (psf).

G The gust effect factor takes into account the turbulence and the resilience of the structure and there are procedures for calculating the gust effect factor. However, ASCE7-02 provides only one value for rigid structures in Section 6.5.8.1, and this is the value that has typically been used for rooftop equipment.

$$G = 0.85$$

C_f The net force coefficient is determined from Table 6-19 of ASCE7-02. Most rooftop equipment is square or rectangular. The conservative approach is to assume that the wind will act on the gross diagonal area. The worst case for a square, rectangular, unit with the wind acting along the diagonal will produce a value for the net force coefficient of:

$$C_f = 1.5$$

This will also cover all of the cases of round rooftop stacks.

Wind Force Computation for IBC 2006 & 2009 (ASCE7-05):

The design wind load for ASCE7-05 is described in Sections 6.5.15 and 6.5.15.1. The basic equation specified for computing the design wind load (F) is identical to that used in ASCE7-02, however, it is to be modified for the mean roof height of the building at the mounting location for the rooftop equipment. The factor used to modify it for building heights less than or equal to sixty feet varies from 1.9 down to 1.0 in a linear fashion based on the size of the equipment relative to the building size. Since the overall building dimensions are not always known, it is recommended that the maximum value of 1.9 be used as a worst case condition. Timothy Reinhold's ASHRAE Journal paper, also recommends that the output force from the equation be increased by a factor of 1.6 for buildings over sixty feet in height. Thus, conservative equations used to determine the horizontal design wind loads for ASCE7-05 will be as follows:

$F = 1.9q_z GC_f A_f$ For $z \leq 60'$ and $F = 1.6q_z GC_f A_f$ For $z > 60'$

Expressing these as horizontal design wind pressures as in the previous section will lead to:

$p_h = 1.9q_z GC_f$ For $z \leq 60'$ and $p_h = 1.6q_z GC_f$ For $z > 60'$

The values for the gust effect factor G and the net force coefficient C_f will remain the same as those for ASCE7-02.

In the commentary of ASCE7-05 (page 300) there is a strong recommendation to include uplift loads in the design of the attachments for rooftop equipment. No guidance is given in this version of the code as to how the uplift forces should be calculated. Again, Timothy Reinhold in his ASHRAE Journal paper recommends the following form for the equations to compute the uplift design wind force acting on the rooftop equipment:

$F_v = 1.9q_z GC_p A$ For $z \leq 60'$ and $F_v = 1.6q_z GC_p A$ For $z > 60'$

Where:

F_v = the uplift design wind load (lbs).

C_p = the external pressure coefficient.

A = the horizontal projected area of the rooftop equipment (ft^2).
Expressing the vertical force equations as vertical design wind pressures as in the previous section will lead to:

$p_v = 1.9q_z GC_p$ For $z \leq 60'$ and $p_v = 1.6q_z GC_p$ For $z > 60'$

Where:

p_v = the vertical, uplift, design wind pressure (psf).

The value for the external pressure coefficient C_p is to be found in ASCE7-05 Table 6-6. It is typically safe to assume that the roof slope is less than or equal to 10° and that the wind can act normal to the roof ridge. The values listed for C_p are negative because they act outward away

from the roof. For components sitting on the roof, it is convenient to drop the negative sign and add any uplift generated by this factor to any other uplift forces that would be present. As such, the value for the external pressure coefficient can be taken to be:

$$C_p = 0.9$$

Wind Force Computation for IBC 2012 (ASCE7-10)

ASCE7-10 accounts for the wind effects on rooftop equipment in Sections 29.5 and 29.5.1. Section 29.5.1 deals with buildings whose mean roof height is sixty feet or less, and Section 29.5 covers buildings whose mean roof height is greater than sixty feet.

For buildings whose mean roof height is sixty feet or less, the horizontal design wind load is given by ASCE7-10 Equation 29.5-2:

$$F_h = q_h(GC_f)A_f \text{ For } h \leq 60'$$

Where:

F_h = the horizontal design wind load (lbs).

q_h = the velocity pressure evaluated at the mean roof height (psf). For the purposes of this document this value will be computed as q_z using previously documented input.

(GC_f) = 1.9 for rooftop equipment. This is allowed to vary in a linear fashion from 1.9 for equipment that is small compared to the size of the building to 1.0 for equipment that is approaching the same size as the building. If unknown, it should be taken as 1.9 for a worst case.

The uplift design wind load is given by ASCE7-10 Equation 29.5-3:

$$F_v = q_h(GC_r)A_r$$

Where:

(GC_r) = 1.5 for rooftop equipment. Here again this is allowed to vary in a linear fashion from 1.5 for equipment that is small compared to the size of the building to 1.0 for equipment that is approaching the same size as the building. If unknown, it should be taken as 1.5.

A_r = the horizontal projected area of the rooftop equipment (ft2).

The design loads may also be expressed as design pressures as follows:

$p_h = q_h(GC_f)$ For $h \leq 60'$ and $p_v = q_h(GC_r)$ For $h \leq 60'$

For buildings whose mean roof height exceeds sixty feet, the horizontal design wind load is given by Equation 29.5.1 of ASCE7-10:

$F = q_z GC_f A_f$ For $h > 60'$

Also for buildings whose mean roof height exceeds sixty feet, the code contains an error that is being corrected. It is intended that the force be computed in the same manner as for the lower structures.

The uplift load should be considered to be:

$F_v = q_h(GC_r)A_r$

And the horizontal design wind pressure is:

$p_h = q_z GC_f$ For $h > 60'$

The values of G and C_f will be as before for ASCE7-02/05.

Section 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.

The output forces from the above equations are based on "ultimate strength" or "LRFD" methodology. Typical component capacity ratings are based on "working stress" or "ASD" based methodology. The two analysis methods differ in how loads are combined when evaluating the worst case load combinations.

1) Because of this, when combining the load with other design loads or when comparing this load to "working stress" based allowables, it must be multiplied by a factor of 0.7. This reduction is not applicable when evaluating the hardware used to attach the componentry to steel structures if the current LRFD (Load and Resistance Factor Design) is used to determine the fastener capacity. It does however, come 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 (where a "working stress" based rating system is still common).

2) Permitted design loads and resulting stresses in the attachment hardware can be increased by a factor of 1.33 in some jurisdictions (but not all) for short term wind and seismic load applications when working with working stress based allowables. A 1.6 factor is permitted when evaluating Screw connections to Timber (NDS (National Design Specification) table 2.3.2).

3) There are many variations in how concrete anchors are evaluated using the various versions of the IBC. These link back to several versions of ASCE-7, and several versions of ACI (American Concrete Institute)-318 appendix D as well as a number of errata that modified these documents over time. Many of the documents build on each other or overrule one another, so deciphering it is confusing at best. This document will not attempt to go through the details of the analysis that is required for anchors and instead will provide a very brief overview:

a) Anchors must be approved by ICC (International Code Council) for seismic and wind applications.
b) The failure modes of pull out, break out, blow out and steel failure must be considered as part of the analysis of each individual anchor.
c) Embedment depth, anchor spacing, edge distance, concrete strength, concrete type (light or normal weight) must be factored into the evaluation process.
d) Depending on the failure mode, significant penalties may be applied to the capacity that must be addressed.

Rather than pursue all of the details of the analysis, it is recommended that anyone needing to evaluate the anchor capacity take advantage of the (typically free) anchor evaluation programs that have been developed by various anchor manufacturers. Note, however, that anchors from one manufacturer cannot be modeled using another manufacturer's software or design tool as the capacities of even identically sized components can differ substantially among manufacturers. For the same reason, anchors cannot be substituted in the field without conducting a full review of the alternate component.

It should also be noted that with virtually every revision of the IBC, the effective anchor capacity has been reduced. This is making it increasingly difficult to find suitable anchors for

large pieces of equipment, especially if that equipment is attached to relatively thin slabs of concrete.

It is also critical that the structural engineer of record on any seismic or wind restraint project review the planned restraint attachment to ensure that the forces that are being applied to the structure at that location will not result in significant unexpected damage or failure that can jeopardize occupants health or well-being.

Section 9
Converting Global Seismic/Wind Forces to Loads at the Restraint Points

Once the global loads have been determined, it will become necessary to convert those loads into forces that will be generated as the result of those loads at the restraint points. This is far from a straight forward procedure and is beyond the scope of this document. Factors that must be considered include:

- The arrangement of the restraint points,
- The type of mounting (hard or soft),
- The types of restraints being used,
- The location of the equipment CG relative to the restraint arrangement,
- The impact of dead, live, seismic and wind load combinations,
- The direction of application for the seismic or wind forces,
- Floor, wall, ceiling mounting applications,
- Forces that may be generated by support springs acting against the restraints,
- Stiffness and/or durability of support structures,
- And others.

The code requires that the worst case combination of loads as well as the worst case direction of load application be considered. The ASHRAE Handbook addresses some simple cases and can offer some initial guidance, but the range of equipment, installation geometries and application types is endless and this portion of the analysis is best left to someone who has some experience in this area.

Section 10
Are there any Special Equipment Requirements?

Current code requirements indicate that for "Life-Safety" equipment, the equipment manufacturer must submit a certificate of compliance indicating that the equipment being

installed can withstand the design seismic forces and remain operational. This certificate must be provided to the appropriate building official for all applications.

Section 11
Housekeeping Pads

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.

If housekeeping pads are poured as a separate pour on top of the structural slab, the pads will require doweling to ensure a continuous load path between the equipment and the building structure.

VISCMA is a non-profit association representing the manufacturers of seismic restraint, vibration isolation and noise control equipment. The primary objectives of the organization are to educate the construction industry on the proper use and application of vibration isolation and seismic restraint and to develop standards to continually improve the industry.

In partnership with FEMA and ASCE, VISCMA also publishes three Seismic Installation and Inspection Manuals designed to assist field personnel.

The association office is located at 994 Old Eagle School Road, Suite 1019, Wayne, PA 19087-1866 and can be reached at 610-971-4850 or info@viscma.com.

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