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Seismic & Wind

Information HVAC Engineers Should Know

by

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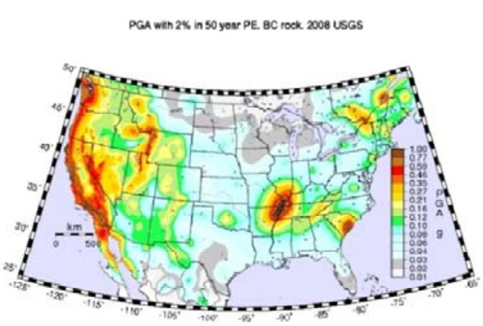
Overview:

Every building is at risk of being subject to some form of "act of God" by natural forces on the earth. Sometimes these forces are predictable based on expectations developed by past history. Yet at other times, like the March 11, 2011 earthquake and tsunami that hit Japan, the forces are beyond the expectations or even the what is considered reasonable anticipation by the professionals who design the buildings.

Professional architects and engineers must determine what is reasonable anticipation and the cost implications to design buildings to the worst case scenario. Building codes must address these issues. Building insurance companies must analyze the risk of insuring buildings subjected to these forces. Each decision carries a level of risk and liability that someone must accept.

A seemingly simple roof curb for a duct termination or fan can create liability for an engineer, contractor and owner if there is no regard to the code requirements for seismic and wind forces. This article gives some information that will be beneficial to consider although it is not an exhaustive discussion of the material and research available.

Seismic Hazard Maps:



2% Ground Acceleration Map (Ref: www.usgs.gov)

In order to understand the statistical significance of why building codes are as they are, a good resource is the USGS. The below excerpts are about as clear as it can be said.

More maps and statistical information can be found at the USGS website www.usgs.gov.

"The U.S. Geological Survey (USGS) recently updated the National Seismic Hazard Maps by incorporating new seismic, geologic, and geodetic information on earthquake rates and associated ground shaking. The 2008 versions supersede those released in 1996 and 2002. These maps are the basis for seismic design provisions of building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land-use planning. Their use in design of buildings, bridges, highways, and critical infrastructure allows structures to better withstand earthquake shaking, saving lives and reducing disruption to critical activities following a damaging event. The maps also help engineers avoid costs from over-design for unlikely levels of ground motion."

"The new 2008 maps represent the best available science as determined by the USGS from an extensive information gathering and review process. Changes will be made in future versions of the maps as new information on earthquake sources and resulting ground motion is gathered and processed." (Ref: www.usgs.gov and Petersen, M.D., and others, 2008, 2008 United States National Seismic Hazard Maps: U.S. Geological Survey Fact Sheet 2008–3018)

It is interesting to note that, although the frequency of earthquakes in the central USA is not as great as in the western part of country, the potential magnitude of forces are greater in the central USA then they are in the western part of the country. This lack of frequency in the central USA has, in many cases, caused small local municipalities to overlook the seriousness of the potential danger of another major earthquake. Architects, engineers, contractors and code officials must continue to maintain a high level of professionalism in adhering to standards and codes and good engineering judgment. Unfortunately the budgets for schools, hospitals and other essential facilities are limited and create a tendency to ignore the necessity of seismic bracing in an effort to minimize the first costs of these facilities. A focus on first cost over safety can create a higher level of risk and liability for the engineer and also puts the occupants in the facilities at higher risk. A person in a hospital in a city in southern Missouri or northern Arkansas could be injured in an earthquake just like someone in a hospital on the western coast in California.

Another major consideration that should be check on every project is how the building insurance companies handle the risks of buildings that are not designed and built in full compliance with industry standards and codes. In addition, the Errors and Omissions insurance companies covering the architects and engineers may also not cover the lawsuits resulting from damage or loss of life in buildings that are designed and built without compliance with current standards, codes. Sometimes professionals want to be the "nice guy" and help their building owners rationalize that the risk is not as bad as the codes imply. These professionals take on a large risk which could put them out of business if their rationalization is wrong and could also cost them their professional license. Sometimes engineers and contractors want to rationalize that if the AHJ doesn't require compliance with a code then compliance is not needed. This is a professional risk that may not be defendable in court. Engineers must realize that in most cases AHJ's are not professional engineers and the AHJ's do not have the liability that the engineer-of-record has on a project. Engineers must use good engineering judgment for the safety and welfare of the building occupants above being concerned about a building construction budget.

An interesting website (http://earthquake.usgs.gov/earthquakes/recenteqsus/) gives a map of earthquakes in the USA in the last 7 days. This website helps give an understanding about the frequency of earthquakes and the volatility of the earth on which we live. The website also has other maps showing such statistics as deadly earthquakes, earthquake density, earthquake statistics, historic earthquakes, largest earthquakes, last earthquakes in each state, seismicity maps, significant earthquakes and other information relate do earthquakes and seismic considerations.

NEHRP:

A good source of for understanding more about earthquakes is NEHRP. Their opening page pretty much explains their mission and purpose:

The National Earthquake Hazards Reduction Program (NEHRP) seeks to mitigate earthquake losses in the United States through both basic and directed research and implementation activities in the fields of earthquake science and engineering.

NEHRP is the Federal Government's coordinated approach to addressing earthquake risks. Congress established the program in 1977 (Public Law 95-124) as a long-term, nationwide program to reduce the risks to life and property in the United States resulting from earthquakes. NEHRP is managed as a collaborative effort among FEMA, the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS).

The NEHRP agencies have established three overarching, long-term strategic goals:
A. Improve understanding of earthquake processes and impacts.
B. Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large.
C. Improve the earthquake resilience of communities nationwide.

For more information on NEHRP, visit www.nehrp.gov, which is maintained by NIST on behalf of FEMA, NSF, and USGS.

Structural Actions:

There is no doubt that seismic forces on a building are forces that a professional structural engineer needs to take into account in the building design. The structural engineer, in coordination with the mechanical engineer, must also ensure that the load path of all equipment mounted on and in the building is transferred to the structure such that these components will not cause damage to the building if they were forced off of their mountings.

1.3.5 Counteracting Structural Actions*.* *All structural members and systems, and all components and cladding in a building or other structure, shall be designed to resist forces due to earthquake and wind, with consideration of overturning, sliding, and uplift, and continuous load paths shall be provided for transmitting these forces to the foundation. Where sliding is used to isolate the elements, the effects of friction between sliding elements shall be included as a force. Where all or a portion of the resistance to these forces is provided by dead load, the dead load shall be taken as the minimum dead load likely to be in place during the event causing the considered forces. Consideration shall be given to the effects of vertical and horizontal deflections resulting from such forces. (Ref.: IBC 2009)*

Equipment Certificate of Compliance – Engineer Responsibility By Code

The IBC directly assigns a duty to the registered design professional to take a specific action. This is in respect to ensuring that the manufacturer of a product has appropriate compliance to the code requirements. It doesn't matter if the AHJ enforces this or not, the engineer is responsible to ensure this occurs as the code assigns this responsibility to the engineer. This is a discussion that should be had between the owner and the engineer and the owner and their building insurance provider who may not cover damage caused by products not in conformance with this code requirement. Suppliers and contractors who ignore this part of the code there is also an added risk and liability to their businesses.

1708.4 Seismic certification of nonstructural components. *The registered design professional shall state the applicable seismic certification requirements for nonstructural components and designated seismic systems on the construction documents. 1. The manufacturer of each designated seismic system component subject to the provisions of ASCE 7 Section 13.2.2 shall test or analyze the component and its mounting system or anchorage and submit a certificate of compliance for review and acceptance by the registered design professional responsible for the design of the designated seismic system and for approval by the building official. Certification shall be based on an actual test on a shake table, by three-dimensional shock tests, by an analytical method using dynamic characteristics and forces, by the use of experience data (i.e., historical data demonstrating acceptable seismic performance) or by more rigorous analysis providing for equivalent safety. 2. Manufacturer's certification of compliance for the general design requirements of ASCE 7 Section 13.2.1 shall be based on analysis, testing or experience data. (Ref. IBC 2009)*

The IBC code is a building performance code. If the MEP systems are designed to the same seismic design force as the building itself, then those MEP systems will continue to operate after a seismic event. Equipment manufacturers need to guarantee "on line" performance through independent testing and analysis as outlined in the code.
This requirement for manufacturers, and consequently their equipment dealers, is a change from all previous building codes. Now when a fully functional system is required by the code, equipment manufacturers and dealers are held liable for the equipment performance after seismic or wind events. Engineers who specify equipment must take this into account in their product specifications and submittal review process.

Contractors are also at risk if they ignore this part of the contract requirements if they attempt to accept cheaper alternative products with no regard for the code requirements. Too many times a contractor assumes that if an engineer approves a submittal in non-compliance with their owner/contractor agreement then they can ignore the code requirements. This is not always true and puts the contractor at risk.

According to the IBC, when an MEP engineer deems a product as a designated seismic system component, then the manufacturer must supply a certificate of compliance stating that the equipment will meet the applicable seismic design criteria for that project. The basis for this compliance can be done by shake table testing or other analyses such as finite element modeling. Historical data may sometimes also be accepted; however, many states have removed this from their adopted state code.

The equipment manufacturer must also supply a label to the equipment that contains sufficient information for the inspector to determine that the installed product is the same as that which was approved during plan review. The special inspector (see later in this article) acts on behalf of the building owner or MEP engineer and verifies that the labeling of the equipment and anchorage or mounting conforms to the previously supplied manufacturer certificate of compliance. Additionally, the Authorities Having Jurisdiction (AHJ) will look for product labeling and certificates of compliance.

Special Inspections - Engineer Responsibility By Code

The IBC addresses an aspect of seismic design and installation that is very likely overlooked by many professional engineers simply because it may not be enforced by the AHJ. However, the code puts the liability squarely on the "registered design professional in responsible charge" to employ an inspector during construction.

Just because the AHJ doesn't enforce this does not relieve the engineer from this code requirement. This should be discussed in the owner/engineer agreement and resolved prior to doing engineering work for any client. The owner in turn would be wise to discuss this with their building insurance carrier to determine if omitting this from a contract with an engineer would void any aspect of their building insurance coverage.

1704.1 General. *Where application is made for construction as described in this section, the owner or the registered design professional in responsible charge acting as the owner's agent shall employ one or more approved agencies to perform inspections during construction on the types of work listed under Section 1704. These inspections are in addition to the inspections identified in Section 110. (Ref: IBC 2009)*

Importance Factor – Ip

It is essential for the HVAC engineer to understand that the component importance factor (Ip) is required to be established and clearly documented in the contract document for every HVAC system. The Occupancy Categories are the starting point to establishing the Ip and then the system within the building determines if the Ip should be a 1.5 or a 1.0, the only two values for this factor.

13.1.3 Component Importance Factor. *All components shall be assigned a component importance factor as indicated in this section. The component importance factor, Ip, shall be taken as 1.5 if any of the following conditions apply: 1. The component is required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems. 2. The component contains hazardous materials. 3. The component is in or attached to an Occupancy Category IV structure and it is needed for continued operation of the facility or its failure could impair the continued operation of the facility. All other components shall be assigned a component importance factor, Ip, equal to 1.0." (Ref. ASCE 7-05)*

In general, all MEP hospital components, from heating and air conditioning systems, generator sets, transfer switches, etc. need to be certified to this IBC guideline. Since hospitals are classified as an "Essential Facility" and most, if not all, of its components have an Importance Factor of 1.5, compliance becomes a requirement for most, if not all, of its operational systems.

Consequential Damage – Crucial Coordination

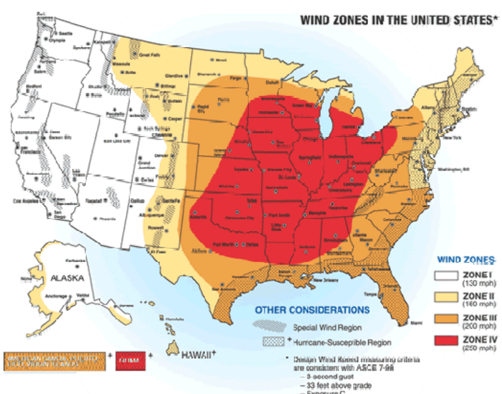
Just how important is coordination of HVAC systems when designing and installing? Very important. If an HVAC system that is assigned an Ip of 1.0 is installed above a system that is assigned an Ip of 1.5 and the 1.0 system could break lose in a seismic event and take down the lower system then the upper system would also need to be installed with bracing as if it were a system with and Ip of 1.5 to prevent "consequential damage" as indicated below.

13.2.3 Consequential Damage. *The functional and physical interrelationship of components, their supports, and their effect on each other shall be considered so that the failure of an essential or nonessential architectural, mechanical, or electrical* *component shall not cause the failure of an essential architectural, mechanical, or electrical component. (Ref.: IBC 2009)*

Wind – Don't Blow It Off

Seismic forces aren't applicable to every part of the country but wind forces are. The code is very clear about the responsibility to take wind forces into account in the building and building system design. Architects and structural engineers may be more in tune with this than some mechanical engineers; however, the HVAC system components can be a very viable risk if not properly supported and designed.

The Federal Emergency Management Agency (FEMA) has developed Wind Zone maps for the USA. These maps show the 3 second wind gusts for the various areas of the USA. These wind gust are the basis of consideration for the development of the building codes.



Wind Zones In The US (Ref: http://www.fema.gov/plan/prevent/saferoom/tsfs02_wind_zones.shtm)

A seemingly simple installation of a "gooseneck" duct termination can be problematic in a wind and rain storm. It isn't just the damage to the roof and equipment that is of concern, it also becomes a more serious concern when water can enter a duct system and distribute in a building causing extensive water damage throughout the building.

The photo above shows an example of how inadequate fastening of an HVAC duct can be blown over and then subject the duct system to rain which can cause a large about of water damage in a building and subject the building to potential mold problems even when the duct is fixed. This is a liability that no engineer, architect, contractor or building owner wants to take unnecessarily by not complying with building codes.
One detail and specification coordination item that should be reviewed on every project is the structural integrity of all rooftop HVAC equipment, ducts and piping on a roof.

This is an analysis that should be part of the contract documents such that the fastening integrity of these items is not left up to the discretion of the contractor without proper engineering analysis to determine the quantity, quality and size of all fasteners. Care should be taken to ensure that the curb and supports are also of sufficient material construction to withstand the forces at the fastener penetrations. This is an analysis that is likely going to require a structural engineer.

Most fan manufacturers do not give any recommendations on the number of sized or spacing of fasteners to hold a fan to a curb so it is not sufficient to rely on “manufacturer’s recommendations” without a clear communication of the forces that the connection is to withstand from winds in accordance with the code requirements.

Louvers:

A growing number of mechanical engineers are taking charge of the louver specifications due to the fact that these are air handling type products that require specification of both pressure loss and water penetration rates as part of the HVAC system. AMCA Publication 511 has a section for “Wind-Driven Rain Test” which tests and gives louvers a rating for both Effectiveness Ratio of water blown through the louver and a Class rating for specifications at both 29 MPH wind velocity with 3”Per Hour and 50 MPH wind with 8” Per Hour of rain.

Keeping water out of buildings has become a high priority in building designs in recent years and this holds true for mechanical systems also where water can enter OA plenums and accumulate if improper water management is not designed into the system. Water blown through louvers can also saturate air filters which can then fall out of place. Specifications of louvers also must take into account the structural stability of the louver under the same criteria as the building wind forces are determined by code requirements. There are also hurricane rated louvers; however, is not within the scope of this article.

Example of AMCA 511 Wind Drive Rain and Hurricane Louvers (Photo Courtesy of Ruskin Corp.)

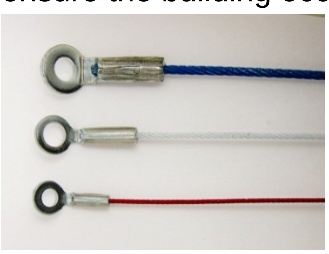
Example of a horizontal blade AMCA 511 Wind Drive Rain Louver (Photo Courtesy of Ruskin Corp.)

HVAC Equipment And Systems Considerations:

Just how much does an HVAC engineer need to know and understand about seismic and wind to design and specify equipment and supports to comply with the forces from earthquakes and wind to be in compliance with current industry standards, codes and standard of care. In general, most mechanical engineers will likely utilize another engineer who specializes in seismic design services and assign this portion of the engineering to an engineer who is specifically in the business to do these calculations.

An engineer who engages in seismic design without the knowledge and competence to do this type of engineering would likely be practicing engineering and using his/her seal in a manner which would not be in conformance with the state statute in which he/she is practicing and would be at risk of disciplinary action.

The forces exerted on buildings during earthquakes cannot be stopped; however, they can be dealt with in a manner that reduces risk and liability and keeps damage to a minimum. Seismic bracing reacts to these forces keeps the HVAC services in place to ensure the building occupants remain safe.



Example of color coded seismic cables (Photo Courtesy of Loos & Co.)

Examples of Seismic Mounts (Photo Courtesy of The VMC Group)

A seismic mount is more than an isolator. An isolator is a product designed to "isolate" the vibration of a piece of rotating equipment or pipe or duct connected to a piece of rotating equipment from the building structure for the purpose of eliminating or minimizing the vibration transmitted to the structure.

A seismic mount is a product designed to prevent the piece of equipment from being forced out of place during a seismic event so that the piece of equipment won't cause damage by being moved out of place or in some cases ensure that the piece of equipment will stay functional during and after the seismic event. The seismic isolator must restrain the equipment from both lateral and overturning forces placed upon it as the seismic wave shakes the building structure which in turn transmits these forces onto the equipment supports. An seismic restraint can and often does function as an isolator also.

Risk and Liability:

The risk and liability of compliance with the standards and codes in any part of the country is the same. Any PE involved with building designs in seismic areas would be wise to understand their risk and liability should they choose to ignore these codes and standards. The same is true for contractors who build buildings in these areas.. The building owner is also at higher financial risk and has liability if they chose to ignore codes related to seismic and wind when their insurance coverage may not cover such events if the building design and construction is not in compliance.

To minimize risk and liability, equipment manufacturers, suppliers, design professionals and installing contractors need to clearly understand their roles and responsibilities as defined in chapters 16 and 17 of the IBC code. In recent years, the insurance industry has put the mechanical and electrical equipment industry on notice. Studies have been done post-Northridge and Hurricane Katrina, proving that buildings designed to the most current building codes have a higher survival rate than those which were not. The industry concluded that proper design and installation does reduce insurance losses and that failure to properly design and install equipment will lead to lawsuits to recover part of their losses.

Policy writers are expected to set premiums based on a building owner's adherence to the code. Insurance claims on MEP systems will be reduced if equipment has been designed to the same seismic and wind load criteria as the building. The cost to replace or repair the MEP systems within buildings is likely the most expensive cost to insurers after a seismic event. Will the insurance industry be willing to pay out claims for equipment that was not in compliance with the building code requirements? This is yet to be seen, but who is willing to continue to take the risk and for what reason?

Professional Considerations:

Every HVAC engineer must take a close look at their design practices, contract document formats, Errors & Omissions insurance coverage, client agreements, design coordination process and submittal review process to ensure that the HVAC products and systems are in compliance with standards and codes in order to minimize their risk and liability. Although there may be a tendency to just do what the AHJ enforces this will not relieve the professional engineer from the duty, responsibility or liability of proving compliance with standards, codes and good engineering practice if there is an event that causes damage or loss of life in a seismic or wind event.