OVERVIEW

Seismic bracing of HVAC components may seem like a non-essential part of a building design. But what if the HVAC system components are installed in a hospital that has surgery suites that may be utilized during an earthquake? What if the HVAC systems are serving a 9-1-1 call center or a fire department or police station? There are certain facilities defined by codes as “essential facilities” that are deemed critical to public safety in the event of a natural disaster, such as an earthquake.

Does it really matter what is shaking the building—and therefore the HVAC system? Does it matter whether it is a surface event or a harmonic tremor? No. A critical facility needs to have its HVAC system stay in operation during and after the seismic event. In our society today, there is a growing consensus (expressed through building codes) that professional architects, engineers, and contractors design and build structures that can withstand seismic events and other such actions by “Mother Nature.”

Note: This chapter contains references to the 2009 International Building Code (due to the fact that many municipalities still use that version of the code). Readers who live in municipalities that use the 2012 IBC will need to confirm the wording of similar code sections.

Seismic events are part of nature. A seismic event is the result of two sections of the earth sliding past one another. The point of separation where the slip occurs is called the fault or fault plane. The hypocenter is the location below the earth’s surface where the seismic event is initiated. The epicenter is the location directly above the seismic event on the surface of the earth.

Sometimes earthquakes cause nonreparable damage to roadways and structures. Sometimes some of the structures within the affected area may be salvageable. And sometimes the utilities inside a structure are damaged by the forces exerted on them by the movement of the building. Although building codes have been in place for years that require buildings to withstand certain anticipated levels of forces caused by earthquakes, these codes are not always enforced. This can cause problems—both because people’s lives and well-being are put in danger, and because the risk of liability is increased for all involved in the design and construction of those buildings. Codes and regulations are more stringent for essential types of buildings, such as hospitals and emergency response facilities that are needed for helping people who may be injured in the earthquake.

Professional architects and engineers must follow building codes and professional standards in designing buildings and the support systems for HVAC, plumbing, fire protection, electrical, and other services within those buildings. AHJs (authorities having jurisdiction) have the duty to review plans and inspect installations to ensure that the buildings do indeed meet all applicable codes. Insurance companies must analyze the risk of insuring buildings that might be subjected to seismic forces.

There are also codes and regulations that manufacturers of products (such as HVAC equipment) must observe to ensure that their products stay functional during and after a seismic event. A product as simple as a roof curb for a rooftop fan or air-handling unit can create liability for an engineer, contractor, or owner if there is no regard to the code requirements for seismic and wind forces.
SEISMIC HAZARD MAPS

In order to understand how and why the need for building codes has developed, a good resource is the U.S. Geological Survey (USGS). The excerpts below state very clearly the reason for seismic hazard maps. More maps and statistical information can be found by consulting the USGS website at 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 the 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.” (Petersen, M.D., and others, 2008, 2008 United States National Seismic Hazard Maps: U.S. Geological Survey Fact Sheet 2008–3018)

An interesting link on the USGS website (http://earthquake.usgs.gov/earthquakes/recenteqsus/) provides a map that shows all of the earthquakes in the U.S. in the last seven days. It serves as a graphic reminder of the frequency of earthquakes and the volatility of the earth on which we live. The website also includes other maps showing such statistics as deadly earthquakes, earthquake density, earthquake statistics, historic earthquakes, largest earthquakes, most recent earthquakes in each state, seismicity maps, significant earthquakes, and other information related to earthquakes and seismic considerations.

It is interesting to note that, although the frequency of earthquakes in the central U.S. is not as great as in the western part of country, the potential magnitude of forces is greater. The relative infrequency of earthquakes in the central U.S. has caused many local municipalities to overlook the seriousness of the potential danger of a 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 costs. A focus on first cost over safety can result in a greater level of liability for the engineer and put the occupants of the facilities at higher risk. A patient in a hospital in southern Missouri or northern Arkansas can be injured in an earthquake just as easily as a patient in a hospital in California.

Another major consideration that should be checked on every project is how given insurance companies handle the risks of insuring buildings that are not designed and built in full compliance with industry standards and codes. Errors and omissions (E&O) insurance companies used by architects and engineers may not cover lawsuits resulting from damage or loss of life if buildings are designed and built in violation of current standards and codes.

Sometimes professionals want to be the “nice guy” and may influence building owners to rationalize that the risk is not as great as the codes imply. These professionals are themselves taking a large risk—one that could put them out of business and cost them their professional license if their rationalization is wrong. Some engineers and contractors want to believe 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, AHJs are not professional engineers and do not have the liability that the engineer-of-record has on a project. Engineers must use good engineering judgment and must be more concerned about ensuring the safety and welfare of the building occupants than trimming the construction budget.
NEHRP

A good source for understanding more about earthquakes is the National Earthquake Hazards Reduction Program (NEHRP), which is a government organization. The NEHRP website explains the organization’s mission and purpose:

“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).”

NEHRP agencies have established three overarching, long-term strategic goals, cited as follows:

► Improve understanding of earthquake processes and impacts.

► Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large.

► Improve the earthquake resilience of communities nationwide.

For more information, visit www.nehrp.gov.

STRUCTURAL ACTIONS

There is no doubt that a professional structural engineer must take seismic forces into account when designing a building. The structural engineer, in coordination with the mechanical engineer, also must ensure that the load path of all equipment mounted on and in the building is transferred to the structure in such a way that these components will not cause damage to the building if they are forced off of their mountings. Here is a direct citation from the International Building Code (IBC):

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. (IBC 2009)

EQUIPMENT CERTIFICATE OF COMPLIANCE

In order to ensure that the manufacturer of a product is in compliance with code requirements, the IBC requires a certificate of compliance and directly assigns this responsibility to the registered design professional. It doesn’t matter if the AHJ enforces this section of the code or not, the engineer-of-record is responsible for making sure that it happens. This is a discussion that should take place between the building owner and the engineer, and between the owner and the building insurance provider (who may not cover damage caused by products that are not in conformance with this code requirement). Suppliers and contractors who ignore this section of the code also risk added liability to their businesses. The relevant portion of the code states:

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. (IBC 2009)

The IBC code is a building performance code. If the mechanical, electrical, and plumbing (MEP) systems are designed to withstand 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.

The certificate of compliance requirement for manufacturers—and consequently for 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 and attempt to accept cheaper, alternative products. Sometimes contractors may assume that if an engineer has approved a submittal that is not in compliance with the owner/contractor agreement, then they can ignore the code requirements too. This is not always true, and puts the contractor at risk.

According to the IBC, when an MEP engineer deems a product a designated seismic system component, then the manufacturer must supply a certificate of compliance stating that the equipment meets 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. Sometimes historical data also may be accepted—however, many states have removed this from their adopted state code. The equipment manufacturer also must 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 the following paragraph) 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, AHJs will look for product labeling and certificates of compliance.

SPECIAL INSPECTIONS

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 code requirement does not relieve the engineer of responsibility. This stipulation should be discussed in the owner/engineer agreement and resolved before any engineering work begins. The owner, in turn, would be wise to consult the building insurance carrier to determine whether omitting this condition from a contract with an engineer would void any aspect of the building insurance coverage. The relevant portion of the code reads as follows:

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. (IBC 2009)

IMPORTANCE FACTOR

It is essential for the HVAC engineer to understand that the component importance factor (Ip) must be
established and clearly documented in the contract document for every HVAC system. The “occupancy categories” are the starting point for establishing the Ip, and then the system within the building determines whether the Ip should be 1.5 or 1.0 (the only two values for this factor). The American Society of Civil Engineers (ASCE) specifies:

**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. (ASCE 7-05)

In general, all MEP hospital components—heating and air conditioning systems, generator sets, transfer switches, etc.—need to be certified to IBC guidelines. Since a hospital is classified as an “essential facility” and most, if not all, of its components have an Ip of 1.5, compliance becomes a requirement for its supporting operational systems.

**CONSEQUENTIAL DAMAGE**

Coordination is crucial in the design and installation of HVAC systems. 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 if the 1.0 system could break loose in a seismic event and take down the lower system, then the upper system also needs to be installed with bracing—just as if it were a system with an Ip of 1.5. This provision is intended to prevent what is known as “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. (ASCE 7-05)

**HVAC EQUIPMENT AND SYSTEM CONSIDERATIONS**

How much does an HVAC engineer need to know and understand about seismic and wind forces in order to design and specify equipment and supports that are in compliance with current industry standards and codes? Practically speaking, most mechanical engineers will utilize another engineer who specializes in seismic design services. Assigning this portion of the task to someone who is specifically trained to do such calculations is a good idea for legal reasons as well. In all likelihood, an engineer who engages in seismic design without the knowledge and competence to do so will not be in conformance with state statutes and will 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 HVAC services in place, and ensures that the building occupants remain safe.

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. The goal is to eliminate or minimize 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 and causing damage and injury. In some cases, properly designed and installed seismic mounts can ensure that the equipment stays functional during and after the seismic event. A seismic isolator must restrain the equipment from both lateral and overturning forces placed upon it as the seismic wave shakes the building. These forces, in turn, are transmitted on to the equipment supports. A seismic restraint can and often does function as an isolator also.
RISK AND LIABILITY

The liability of noncompliance with applicable standards and codes is the same in any part of the country. All professional engineers involved with building design—and especially those who work in areas where the probability of seismic events is high—would be wise to understand the potential risk should they choose to ignore relevant codes and standards. The same is true for contractors. Building owners are also at higher financial risk if they choose to ignore codes related to seismic and wind events. Their insurance may not cover such events if the building design and construction are 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. In recent years, the insurance industry has put the mechanical and electrical equipment industry on notice. Studies done after the Northridge earthquake of 1994 and Hurricane Katrina in 2005 proved that buildings designed to the most current building codes have a higher survival rate than those that are not in compliance. The industry concluded that proper design and installation does in fact reduce insurance payouts, and that failure to design and install equipment properly leads to lawsuits as policy holders attempt to recover their losses. Policy writers are expected to set premiums based on a building owner’s adherence to the code. Insurance claims on MEP systems are 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 is not in compliance with building code requirements? Who is willing to continue to take that risk, and for what reason?