



Seismic Restraint

Preventing Damage to HVAC Equipment and Systems

By **James R. Tauby, P.E.**, Member ASHRAE

This past year has been a tough one for earthquakes. We have seen major earthquakes throughout the world, most recently in Japan, as well as Chile, Haiti and New Zealand. These massive earthquakes take a heavy toll on human life and buildings. Older buildings that survive structurally rarely have their utilities such as the HVAC&R, plumbing and electrical systems remain functional. Newer buildings built to more recent building codes have a better survival rate.

In the 1994 Northridge, Calif. earthquake, it is estimated that as much as 70% of the damage to buildings that survived structurally was caused by the

failure of the HVAC&R, plumbing, fire protection and electrical systems. But this does not have to happen. The U.S. building codes have minimum require-

ments for the design and restraint of HVAC, plumbing, fire protection and electrical systems that are considered non-structural components within the building.

Building Codes

Building codes were thoroughly covered in April's article "Earthquake: New Codes Provide Tools, But We Need to Ensure Compliance," by James A. Carlson, P.E. and Robert E.

About the Author

James R. Tauby, P.E., is the chief executive engineer for Mason Industries and is a past chair of ASHRAE's Technical Committee 2.7, Seismic and Wind Restraint Design. He is a distinguished lecturer for ASHRAE on the topics of seismic restraint and vibration isolation. He was the lead author of ASHRAE's "A Practical Guide to Seismic Restraint."

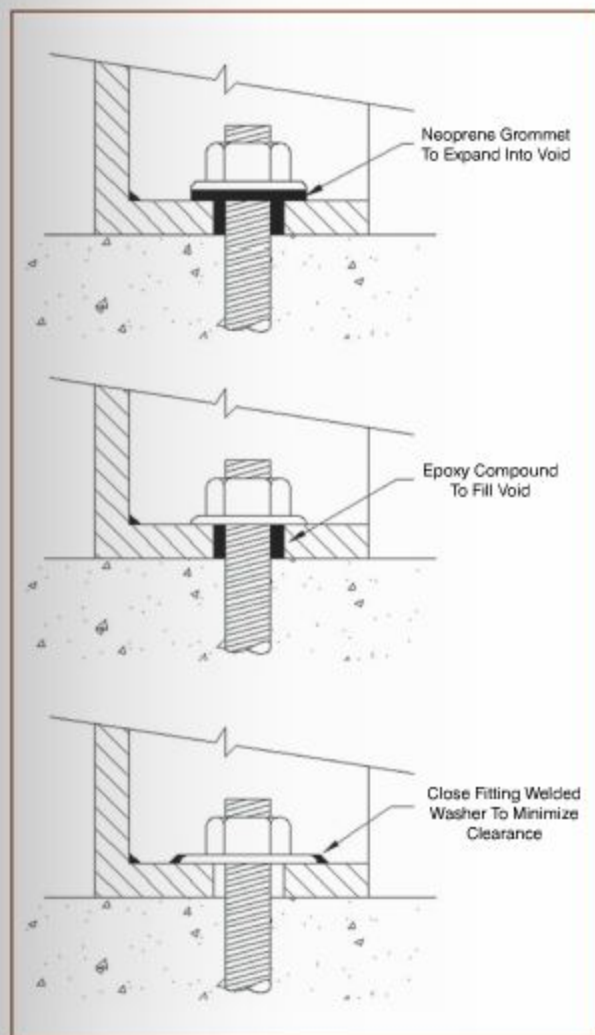


Figure 1: Three methods for reducing bolt shear.

Simmons, P.E. The design of the seismic restraints does take into account the building occupancy, location based on the U.S. Geological Survey, system ruggedness and location within the structure in relation to intermediate floors as well as the roof.

Practical Guide to Seismic Restraint

ASHRAE published *A Practical Guide to Seismic Restraint* in 1999. This manual covers all of the HVAC&R systems in a building. It also includes chapters on building codes, specifications, housekeeping pads, bomb blasts, residential equipment, equipment fragility levels and a chapter on the basics of earthquakes. The manual is available at www.ashrae.org/bookstore. A revision of the manual is planned for publication later this year. Up-to-date informa-

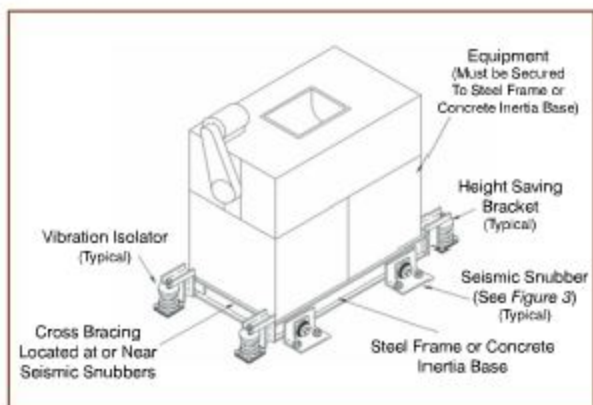


Figure 2: Equipment on steel frame with separate seismic snubbers and vibration isolators.

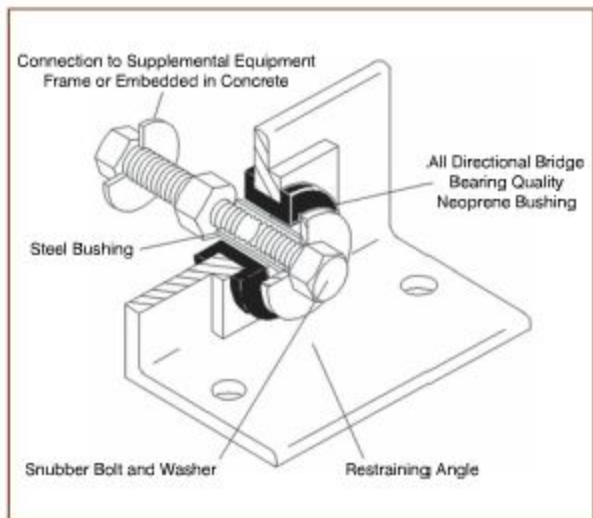


Figure 3: Typical seismic snubber as used in Figure 2. Note: Minimum four snubbers required per base.

tion on codes is in the *2011 ASHRAE Handbook—HVAC Applications*, Chapter 55, (also *2007 ASHRAE Handbook—HVAC Applications*, Chapter 54).

Specifications

The most important way to ensure a project is constructed safely is to have a complete specification covering seismic restraint of piping, ductwork, electrical supply systems and all mechanical and electrical equipment. This requires a properly prepared set of construction documents, a detailed review by a professional, and approval of shop drawings and field enforcement. Seismic restraints should be looked at as an engineered system, not as a selection of hardware from a catalog. Calculations or prior testing must prove that the restraints are more than adequate for the project.

Floor-Mounted Equipment

Floor-mounted equipment must be secured to the structural floor. Attachments must be designed and installed properly to achieve at least the specified minimums. Attachment methods include bolting directly to the slab, attaching to the slab by way of a combination of seismic restraint/vibration isolator, or by the use of vibration isolators and separate seismic snubbers. When equipment is bolted directly, the back and forth hammering movement during a seismic event can cause the bolts to shear off because of the space between the bolt and the bolt hole. See *Figure 1*, Page 21, for three options to avoid this problem.

For equipment installed on the roof and subject to wind loads, the equipment restraint system shall be designed for the higher of the two, seismic or wind.

Figures 2 and 3, Page 21, show typical equipment restrained with separate isolators and seismic snubbers.

Housekeeping Pads

One of the most overlooked systems in the building are the housekeeping pads. Housekeeping pads provide the load transfer between equipment and the structure. Look at the photo at the beginning of the article. The pump was

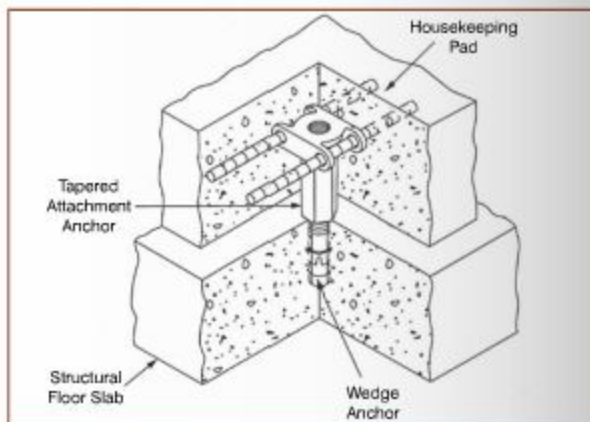


Figure 4: Housekeeping pad anchorage.

attached to the housekeeping pad inadequately. In addition, the pad was not anchored to the structural slab, nor was it adequately reinforced. This allowed the slab to move and break, leaving this system non-workable. See *Figure 4* for typical proper reinforcement in the housekeeping pad and anchorage of the pad.

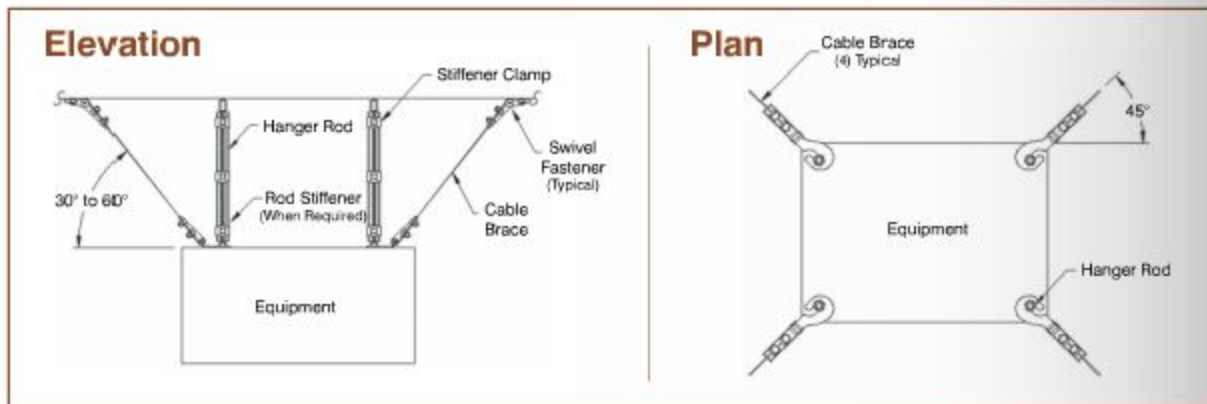


Figure 5: Flexible cable bracing for suspended equipment.

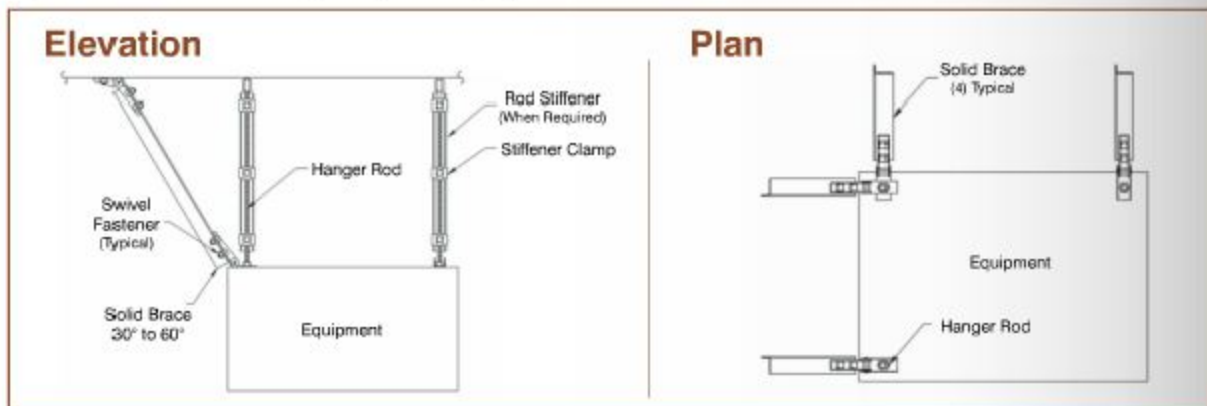


Figure 6: Rigid bracing for suspended equipment.

Suspended Equipment

All suspended equipment must be braced with either flexible cable or with rigid steel. Vibration isolated equipment must use flexible cables, to avoid shorting out the isolation. See *Figures 5 and 6*, Page 22, for typical suspended equipment bracing.

Suspended Piping

All piping requires seismic bracing, down to a minimum size as specified. Like suspended equipment, bracing can be either flexible cable or rigid steel. The weak points in these systems are where the piping attaches to equipment and valves.

Where piping attaches to equipment, flexible connections will accept the differential motion between piping attached to the ceiling and equipment attached to the floor. These flexible connections must be

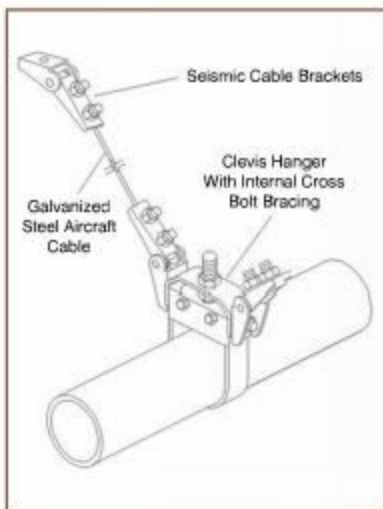


Figure 7: Flexible cable bracing for pipe.

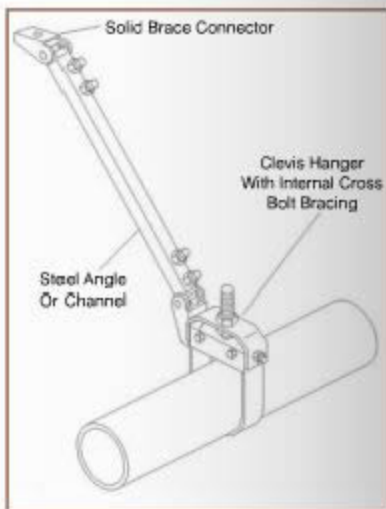
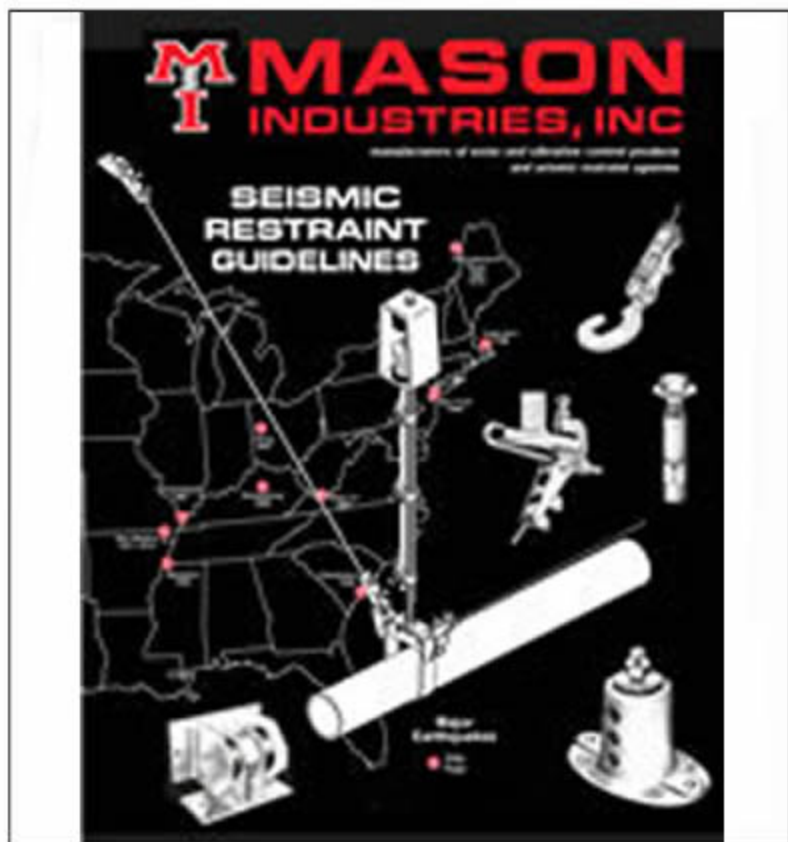


Figure 8: Rigid bracing for pipe.

of a type and size to handle the calculated movements.

Piping systems can be high-deform-

ability materials that are welded or brazed, high or limited deformability material with compression or grooved



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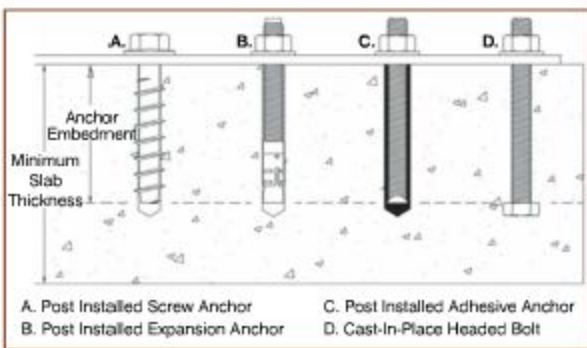
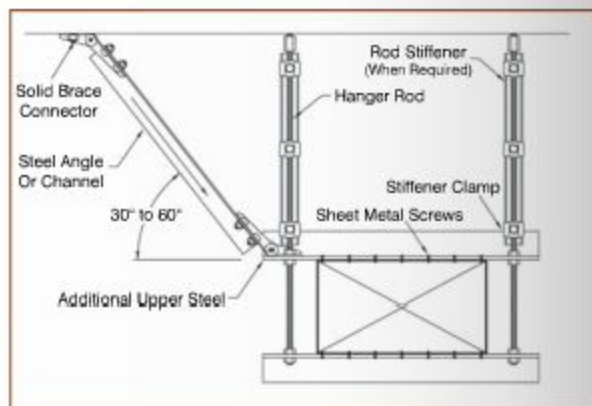
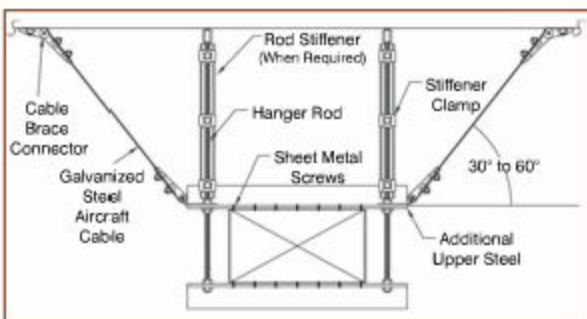


Figure 9 (top left): Flexible cable bracing for ductwork. **Figure 10 (top right):** Rigid bracing for ductwork. **Figure 11 (left):** Four methods for attaching to concrete.

couplings, threaded and bonded, or low deformability such as cast iron, glass, non-ductile plastic, etc. Welded pipe is the most rugged, and can accept higher seismic loads. The high or low deformability piping using grooved couplings, etc., is next, but at lower load ratings. Low deformability piping ac-

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cepts the lowest loads. See *Figures 7 and 8*, Page 24, for piping restrained with flexible cable and rigid bracing. Flexible cable have to be used on systems that are vibration isolated.

Ductwork

Ductwork requires bracing with very few exceptions. It can be braced with either flexible cable or steel sections.

Vibration-isolated ductwork requires the use of flexible cable. Ductwork made from high-deformability materials that are welded or brazed can accept the most load. Ductwork made from high or limited deformability materials that are not welded or brazed accept lower loads than the welded ductwork. The low deformability ductwork such as cast iron, glass, or non-ductile plastic can handle only very low seismic loadings. See *Figures 9 and 10*, Page 26, for a typical flexible cable and rigid duct brace.

Connections

All seismic restraints must be rigidly attached to the building structure. This is done with the use of post installed anchors including wedge, screw or adhesive. The only anchor not post installed is the embedded bolt. See *Figure 11*, Page 26, for details of typical connections.

Anchors must have certifiable allowable seismic loads according to the building code. This testing is done in different strengths of cracked and uncracked concrete, and some are also tested in the underside of concrete decks using a minimum of 20 gage steel decking. Anchors must be as per ACI 318 and certified by an accredited agency such as the International Code Council Evaluation Service (ICC-ES).

If the connection is to wood, then lag screws can be used for the attachment of restraints. Lag screw connection design can be found in the "National Specification for Wood Construction," as published by the American Wood Council. The design is dependent on the diameter, length of penetration, screw material, specific gravity of the wood, edge and end distances and screw spacing.

If the connection is to steel, then the bolts should be designed in accordance with the American Institute of Steel Construction's "Manual of Steel Construction" 9th edition. Steel bolts are allowed a one-third increase for temporary seismic or wind load. ●

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