

# The 10 Biggest Problems Contractors Deal With When Installing Seismic Restraints

## General

### (1) Knowing When Restraint is Required

Large areas of the country are now being forced to include some kind of seismic restraint due to the adoption of the IBC Code and its more stringent seismic design requirements. This is particularly true for emergency treatment centers, essential service structures, or facilities that contain some form of hazardous materials. There are only two significant areas of the country completely exempted by code from restraint requirements: a belt running generally northward from western Texas to Minnesota and the tip of the Florida Peninsula. The code will require some level of restraint (at least in critical facilities) at most other locations.

Even for non-critical facilities, the IBC Code will usually require some form of restraint in the following regions: New England, the south central US (in a band several hundred miles wide from Charleston, South Carolina to a point about 150 miles west of Memphis, Tennessee) and everywhere west of the Rocky Mountains.

Increasingly, customers will specify some form of restraint to ensure continued operation of a facility or in an effort to reduce insurance premiums, even in areas where the IBC code does not require restraint. It is critical that specs for individual projects be fully understood in this regard.

The IBC Code is quickly becoming the code of the land. Since FEMA has targeted compliance with seismic standards as critical, it should be assumed that some form of seismic compliance will be required before a final occupancy permit is issued for any structure built in the above areas.

## Anchorage Issues

### (2) Equipment Location in the Building

Research has shown that the force generated in a building increases as one rises through the structure. Surprisingly, the total height of the structure is not as important a factor as is the location of equipment in that structure relative to the roof. The IBC Code addresses this condition by requiring that the design used when specifying equipment anchorage includes forces that increase by a factor of 3 as equipment locations move upward from grade to the roof.

To the designer and installation contractor, this means that sturdier equipment is required along with a significantly more robust anchorage system. In relatively low-level seismic areas, this requirement is often insignificant, but in seismically active areas it can add substantial cost and can significantly impact the design of the

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Toll Free (USA only): 800-959-1229  
International: 614-889-0480  
Fax: 614-889-0540  
World Wide Web: [www.kineticsnoise.com](http://www.kineticsnoise.com)  
Email: [sales@kineticsnoise.com](mailto:sales@kineticsnoise.com)

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equipment, structure, and restraint system. Common devices frequently used in the past will no longer be suitable and more exotic devices are needed. In extreme cases, major design changes are necessary to meet the new force requirements.

It is most cost effective to locate heavy equipment at lower levels within the building envelope wherever feasible. If heavy equipment is to be located on upper floors (or on the roof of even a one-story building) in an area with potentially high seismic accelerations, addressing seismic issues early can avoid costly delays, significant redesign, and possible retrofit.

### (3) Anchorage to Concrete

Concrete has long been identified as a weak point when used in areas exposed to seismic events. The addition of anchorage holes in the concrete provides locations for stress cracks to develop. These cracks open up and allow conventional anchors to easily pull out. Because of the requirement to withstand cyclic pounding during an event, wedge-type or other special seismically rated anchors are required. Approved anchors have been tested and carry an ICBO rating based on test results. These ratings vary by size and by anchor manufacturer. It is critical that the restraint system design specifies a particular anchor by size and source and that the anchor used conforms to this specification.

New code requirements mandate that undercut anchors are to be used for 10 horsepower and greater equipment that is hard mounted. At the time of this writing, the only viable undercut anchor available in the United States is the HILTI HDA-P or -T series anchors. These are metric, but they can interface well with imperial-based mounting holes. About 25% more labor time should be assumed for their installation because of the undercut requirement. Detailed installation instructions are available in ICBO report ER-5608. This document can easily be downloaded from the Internet for reference.

In addition, the ratings allowed for anchors in seismic applications are considerably less than ratings for similar-sized A307 bolts. If the equipment being restrained is isolated, the shock caused by the motion of the equipment pounding against restraint snubbers is more likely to damage brittle anchors than it is to damage the more ductile A307 bolts. To account for this, an additional factor must be applied to the load when using anchors for the final attachment to concrete. The net result is that equipment using A307 through bolts for attachment have a considerably higher seismic rating than does equipment attached with the same sized post-installed anchors.

The code severely penalizes applications where the embedment depth is less than 8 anchor bolt diameters (i.e., 4 inches for a ½ inch anchor). Since anchors must be embedded in a monolithic slab, the thickness of the concrete beneath the equipment often becomes the factor that limits the anchor size. Since there should be at least 1 inch of cover over the end of an anchor, the minimum slab thickness for a ½ inch

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diameter anchor should not be less than 5 inches. If more capacity is required, either a thicker slab or an array of several ½ inch anchors would be required to obtain an appropriate rating.

Similar to embedment restrictions, anchor spacing and edge distance issues can also significantly reduce the anchorage capacity. Care should be taken to allow sufficient edge distances to attain full-rated anchor capacities. Where arrays of anchors are used to develop sufficient capacity, it must be verified that sufficient slab area exists to ensure that these minimum dimensions are not violated.

It is still common to find designs that require equipment located high up in buildings in seismically prone areas to be anchored to concrete. In many cases a review of the installation shows that this configuration cannot meet code requirements. In these cases, the options are typically limited to one of three things. 1) Add a steel attachment structure that ties into the building steel, 2) design an appropriate frame that allows significantly more anchors to be placed over a larger area, 3) bolt the equipment down using bolts that go through the floor (or roof deck) and which include a backer or “fish” plate on the underside of the slab.

#### (4) Concrete Housekeeping Pads, Curbs, and Piers

A frequent solution used to obtain a reasonable embedment depth for larger diameter anchors is to add a housekeeping pad. This practice increases the slab thickness in the area where the seismic anchors are fitted. As previously mentioned, it is a code requirement that anchors be embedded in a monolithic pour. This requires that either the pad be poured concurrent with the structural floor slab and the combined thickness meets the requirement (not likely), or that a separate pad is added that is independently thick enough to meet the requirement (more common).

The housekeeping pad must be adequately reinforced and doweled with sufficient connections to ensure that it will neither shatter nor come loose from the floor during a seismic event. Even with larger (and deeper) anchors at the restraint locations, it is the normal practice to attach most housekeeping pads to the structural floor slab beneath it using a large array of smaller (and shallower) anchors. All such housekeeping pads should be designed based on the seismic application. Kinetics Noise Control can offer design tables and general details for this purpose.

Concrete curbs or piers are occasionally included on roof decks to aid in flashing the roofing material while leaving a support point for equipment. Where these are used, size becomes critical as the minimum edge distance and anchor spacing limits frequently dictate a pier considerably wider than might otherwise be expected. For example, if a hard-mounted piece of equipment is being attached to several piers using (1) ½ inch anchor centered on each pier, the minimum edge distance for an HILTI HDA-P is 7-3/8inch. This means that the minimum pier size would be 2 x 7-3/8

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or 14-3/4 inches square. If using a plate with (4) 1/2 inch anchors per pier, the minimum anchor-to-anchor spacing (for 1/2 inch anchors) is 14-3/4 inches and thus the minimum size of the pier becomes 29-1/2 inches square.

**(5) Equipment Durability and Interfacing Support Members**

Equipment qualification is a new issue being addressed in the IBC. The code indicates that if any piece of equipment is used in a seismically active area, it should be capable of withstanding the design seismic forces for that area (as defined by the ground acceleration and basic building and foundation parameters) and continue to operate. In the past this was not a requirement. The equipment manufacturer should be advised that the equipment is going into a seismically active area and should be made aware of the seismic forces applicable to the particular piece of equipment, including the elevation in the structure. In turn, the equipment manufacturer should provide the installation contractor with appropriate documents ensuring that the equipment is suitable for the application.

Frequently, the equipment is qualified as if it were to be hard mounted to a slab or other support structure. The dynamic loads in this case are considerably less than those used if the equipment is isolated and setting on several independent restraints. If this is the case, the contractor should make a note of it. Some form of rigid frame may be required in cases where the equipment is equipped with light structural connection locations to prevent damage that may result from high twisting or bending loads generated by directly connected isolators/restraints. The equipment manufacturer can best advise if a frame is needed (as they are the only ones who really know how the equipment is built) and they should indicate the need for a frame if required.

**(6) Restraint of Tall, Narrow, Floor mounted Equipment**

Tall, narrow pieces of equipment can be difficult to restrain, particularly if isolated. Because the restraint points at the floor are relatively close together, small motions at the floor result in large motions at the top of the equipment. In addition, small lateral forces acting on the equipment's CG generate large uplift forces at the restraint points. Where possible, this equipment should be restrained to a wall, braced with a frame that has a relatively wide base, or set on top of an inertia mass to shift the CG downward. Another option is to use cable restraints to limit lateral motion (if cable restrained, the restraints must tie to the same surface as the equipment mounting feet).

Top-heavy equipment can be a particular problem outdoors (where wind effects can cause wild gyrations) or when mounted on relatively high-deflection springs (which offer little resistance to rocking loads).

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## Piping/Duct Issues

### (7) Not Enough Room to Fit Restraints

The most frequent issue that comes up relative to the restraint of piping, duct, or other ceiling-mounted systems is that there is often not enough room for restraints if the restraints are arranged in the conventional fashion. Lateral restraints often interfere with walls, other duct or piping systems, or equipment. Creativity is oftentimes required to arrange restraints in ways that can fit. For example, on a trapeze, lateral restraint cables can be arranged in an "X" instead of in a "V" or can be grouped together on one hanger rod instead of having one on each end of the trapeze. In some cases, attaching to a wall may be better than attaching to the ceiling. Typical details showing a broad variety of options can be obtained from Kinetics Noise Control.

In many cases, knowing the requirements concerning restraint locations which can be used to resist forces for two or more different runs can save a significant number of restraints and reduce the difficulty of installation simply by reducing the quantity of restraints required.

### (8) Mixing Cables and Struts

When arranging restraints along a run, cables and struts cannot be mixed. Thus a given run must be either all cable or all strut. Both have advantages and disadvantages that should be understood. When using cables, each restraint point requires that at least two cables be fitted. As a trade-off, the cables do not load hanger rods in tension and concerns about tensile forces in the hanger rods need not be addressed. When using struts, only one strut is required at each restraint location. Struts do, however, load hanger rods in tension and frequently require that larger hanger rods be fitted or that the spacing between adjacent restraints be reduced to one-half or one-quarter of that allowed for cables.

Cables are the preferred method of restraint if the piping or duct system is isolated.

If the hanger rod length becomes excessive, a reinforcement member is required on the hanger rod to prevent buckling of the hanger when subjected to large seismic forces. This is required for both cable or strut restraint systems.

Tables and design information for installation of both cable and strut systems are available from Kinetics Noise Control.

### (9) Adherence to the 12" Hanger Rod or the Small Duct or Pipe Exception Rules

If installing a system tight to the ceiling to take advantage of the 12 inch hanger exclusion rule, the 12 inch dimension is measured from the top of the pipe or duct if the duct or pipe is individually supported without a trapeze bar. If supported by a trapeze, the 12 inch dimension is from the top of the trapeze bar. In all cases, the

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measurement is from the uppermost attachment point to the structure.

All supports for a given run must comply with the above to apply the 12" rule.

An additional requirement of the 12 inch rule is that the hanger rod must include a non-moment generating (free-swinging) connection to the structure. This is to allow the pipe or duct to swing without stressing the hanger rod. A swivel or isolation hanger can accomplish this function. If using an isolation hanger, a vertical limit stop must be positioned on the hanger rod just below the isolator housing. Thus when subjected to an uplift load, the limit stop will come into contact with the isolator housing and prevent significant upward motion of the rod.

If supporting a trapeze, the largest pipe or duct on the trapeze must be used to determine if the run can be considered for exclusion. (Note: The older codes only allowed individually supported pipes or ducts to be eligible for exclusion using the size or 12 inch rule. There is no such limitation in the IBC Code.)

#### (10) Axial Restraint of Thermally Expanding/Contracting Piping

It can be a challenge to axially restrain pipes that must be allowed to expand or contract due to thermal considerations. It is often possible to install a lateral restraint at a short dogleg or at the adjacent leg at the beginning or end of a run. As long as these are located within 24 inches of the centerline of the run, which is to be axially restrained, this is permitted.

The addition of flex joints or expansion fittings between independently restrained segments of a run allows the individual segments to be restrained in a more conventional fashion.

Where growth or shrinkage is expected, no more than one axial restraint is to be used for a given run of pipe unless some form of expansion compensation joint is fitted between the restraints.

A double roller (one top, one bottom) is needed to transfer upward forces generated by the restraint acting on the pipe back into the supporting hanger rod when roller supported pipes are directly braced to the ceiling with cables or struts. When pipes are mounted on trapezes and the trapeze is fitted with a roller, bracing the trapeze will not axially restrain the pipe.

The bracket fitted to the pipe to which the restraint connects must be either welded to the pipe or sufficiently clamped to allow transfer of the full restraint force. If the pipe is insulated, a hardened area or welded saddle must be used that is strong enough to meet the seismic design needs.

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