Attachment of Restraints to Structure

Introduction:

Unlike the connection between restraints and equipment (which is almost always a metal to metal connection), the connection to structure can be made to a wide variety of materials. The most frequent connection is to concrete, but connections to structural steel, wood and gage materials are also common. As the structural connection has the potential to be the weakest link in the anchorage chain, proper treatment is critical.

In addition to being critical to the anchorage of the equipment, the structural connection also has the potential to impact the durability of the structure. Because of this, all connections to structure should be reviewed with the engineer of record prior to installation to ensure that the attachment method chosen can not result in a structural weak spot that can cause an unintended failure in the building or other dangerous situation.

Of particular concern are the following:

1) Connections to structural steel involving drilling holes or otherwise weakening the structure.
2) Connections to post-tensioned concrete slabs involving drilling into the slab.
3) Bolt or screwed connections to the narrow edge of wooden beams.
4) Any connections to gage material.

Connections to Concrete

Because of the brittle nature of concrete, it is particularly susceptible to failures that result from the pounding loads generated by earthquakes. As a result, the anchors selected must be sized conservatively. While cast in place anchors are preferable from a loading standpoint, the ability to properly locate them at the time of the pour is very low and they are rarely used in equipment mounting applications. If this hurdle is overcome, they can be sized using conventional anchor sizing procedures as identified in the current version of ACI 318.

Most commonly, post-installed anchors are used. While these can be installed at the time the equipment is placed, they do not have the same positive grip as to the cast in place anchors. As a result, reduced capacities based on ICBO/ICC tests must be used and frequently factors are added to increase the design forces used in the analysis to further ensure that the anchors will remain functional.

For equipment that is mounted on springs, wedge type anchors are preferred. These anchors are relatively easy to install, continue to expand as they are exposed to tensile loads and offer added confidence that they will continue to function, even in cracked concrete.

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Also used in floor mounted applications are adhesive anchors. These offer good performance, but the installation is more critical. They are unacceptable for overhead applications or in areas where they could be subjected to chemical attack however.

Although other anchors types can be used (provided they have an ICBO/ICC rating), their allowed capacities are such that they are not viable alternates. Kinetics Noise Control provides seismically rated wedge type anchors for most applications.

When equipment is not isolated and is under 10 hp, the same wedge anchors used above can be selected. If the equipment is isolated however, depending on the building code in effect for the project, undercut anchors may be required. These anchors require that a hole be drilled and then be modified to include an oversized pocket at their base. These pockets can be created with a special tool or in some cases, can be cut with the anchor itself. These pockets offer a more positive lock for the bolt than can be obtained with a wedge type anchor.

When using post-installed concrete anchors, all anchors are to be embedded 8 bolt diameters and must retain at least a 1" cover of concrete between the bottom of the hole and the opposite face of the concrete. For slabs on grade, this value should increase to at least 1-1/2". Because of this requirement, the size of the thickness of the concrete has a direct impact on the maximum permitted anchor size. For instance, if the slab to which the equipment is to be attached is 4" thick, this means that with 1" of cover, the maximum embedment can be 3" and thus the maximum anchor size can only be 3/8" diameter. If the required anchor is larger than this, some special treatment of the floor slab is required.

All anchors are rated for installation into a single, uninterrupted layer of concrete. Because of this, unless poured at the same time and as one piece with the floor slab, the added thickness of a housekeeping pad cannot be added to the floor slab thickness when determining the maximum allowed anchor embedment. Instead, the housekeeping pad by itself, must be adequately thick to accommodate the anchors and must be tied with an array of smaller anchors to the structural floor. There is more information on designing housekeeping pads in the appendix of this manual.

Because post-installed anchors are dependent on friction for their capacity, it is critical that they are torqued to the appropriate level. Also, because anchors of similar sizes as manufactured by different manufacturers do not possess equal capacities, it is not permissible to substitute away from those that were assumed in the evaluation and certification process. All Kinetics Certifications are based n the use of Kinetics Noise Control provided anchors, torqued in conformance with the anchor torquing data provided in the submittal information and also available in the product section of this manual.

An optional attachment method is to through drill floor slabs above grade and install the restraint device using bolts and nuts. If this is done, any factors that may have been used

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in the analysis to derate the anchors, can be ignored.

A second option is to cast an oversized embedment plate into the floor in the approximately location of the required restraint device. This plate can be interfaced with the steel reinforcement in the slab to ensure that it will not pull out. When the equipment is installed at some later time, the restraints can be welded to the embed plate and the entire restraint arrangement can be treated as though it was attached to concrete.

Connections to Structural Steel

There are two different types of steel structures to which equipment may attach. The first is a purpose built structure that was designed specifically to support the equipment being restrained and the second is a structure whose primary design intent is based on the capacity of the building envelope to withstand building design loads.

In the first case, attachment holes are common and have typically been accounted for in the design of the structure. The use of bolts to attach the equipment is common practice, but should be coordinated with the structure's designer.

In the second case however, the attachment of equipment is really an afterthought. While the structure would globally have been designed to have adequate capacity for both its intended building function and equipment support, the addition of holes or locally applied stress concentration can weaken it to the point that serious building structural issues can emerge. Under no circumstances should the structure be modified in such a way that it would be weakened without prior review of the structural engineer of record. Connections to the building structure are normally accomplished by welding components to the structure. These components can include holes or other bolting provisions. If the attachment process involves the removal of fire proofing material on the steel, it must be replaced prior to completion.

When fitting bolts, they are not permitted to exceed the nominal hardware size by more than 1/8". Thus the largest hole permitted for a 5/8" bolt is 3/4". Slotting this hole for alignment is not permitted and if required, the hole must be repaired to limit the clearance to 1/8" prior to the installation of hardware. All bolts are to be tightened in conformance with normal practice.

Connections to Wood

There are a wide variety of wood sections to which people attach equipment. These range from heavy timber members and engineered lumber to roof sheeting. When seismically restraining equipment, connections should be made to structural grade or "engineered" lumber.

Where possible, the preferred connection is to through-bolt the wood member and

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incorporate a load spreading washer plate (or fishplate) on the back side of the wood to prevent crushing.

Where it is necessary to screw into the wood, lag screws inserted into properly drilled holes can be used providing the following rules are followed:

1) The edge distance from the center of the screw hole to the edge of the wooden member in which it is inserted must be at least 1-1/2 bolt diameters.
2) The end distance (from the bolt to the end of the wooden member in the direction of the grains axis must be at least 7 bolt diameters.
3) Spacing between bolts must be at least 4 bolt diameters.
4) Embedment is adequate for the design loads expected.

Of these items, the first 3 are relatively straightforward. The last item is more ambiguous and needs further explanation. The bolt capacity is a function of many factors and should be sized specifically for the application under review. The density and type of the wood, the angle of the screw relative to the grain and the redundancy of the connections all have significant impact on the rating of the connection. In order to achieve the full rated capacity of the restraint device (if connected with lag screws), the limiting capacity of the screw must be a metal failure in the screw itself. In general, this means that for a reasonably dense grade of structural lumber and a screw mounted at 90 degrees to the grain axis, an embedment depth of 9 diameters is needed to achieve full capacity. Further information on the design of lag screw connections is available in the NDS/ASD *National Design Specification for Wood Construction Manual* published by American Forest and Paper Association / American Wood Council or Section A7.3 in the Appendix portion of this manual.

As with connections to steel, it is mandatory that the structural engineer of record is aware of and approves connections to wood structures because of the possible adverse affect that equipment attachment might have on the ability of the structure to carry primary building loads.

Connections to Gage Materials

The most common applications that involve connections to gage materials involve curbs and roof mounted equipment. In these cases, if light equipment is involved (like mushroom fans), connections directly to sheet metal can frequently be adequate. In order to be successful however, the connections need to be made up of a series of small fasteners spaced evenly around the component being anchored. In general, applications involving screws larger than #10 cannot be directly connected to gage materials.

Where these connections can be made, it is also mandatory that the gage materials themselves are also attached to larger structural elements with a series of smaller connections. Again these must be designed such that the can transfer any seismic loads forced into them by the equipment back into the structure without damage.

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