6.6 Installation Notes, Safety Warnings, and additional guidelines

For those details for which the non-engineered approach is acceptable, a few words of caution are in order. Many items shown in the upgrade details can be purchased at any hardware store, but it is important to select hardware that is appropriate for the task at hand. A toggle bolt mounted in gypsum board may hold a light picture frame on the wall, but it is not appropriate for any of the details shown in this guide. At the other extreme, a 1-inch diameter bolt is too large for a 2x4 wood stud, since the hole required to accommodate the bolt will unacceptably weaken the 1 1/2- inch wide stud and does not meet the required edge distance in NDS 2005 *National Design Standard Specifications for Wood Construction* (AFPA/ANSI, 2005). The following discussion provides general guidelines on hardware selection and installation procedures for the details shown in this chapter.

FEMA 412 *Installing Seismic Restraints for Mechanical Equipment* , FEMA 413 *Installing Seismic Restraints for Electrical Equipment*, and FEMA 414 *Installing Seismic Restraints for Duct and Pipe* contain additional details for mechanical, electrical, and plumbing components. These guides include lists and tables covering many specific types of MEP equipment with recommendations on the type of detail, housekeeping pads, and anchorage hardware to use. In addition, safety warnings that are important for anyone working on or around electrical equipment are included in these guides; these warnings are repeated here in Section 6.6.8.

6.6.1 Positive Connections

The objective of nonstructural anchorage or restraint details is to provide what engineers refer to as a positive connection between the item and a hard attachment point, such as a structural wall, braced partition, concrete floor, or built-in countertop. Positive connections generally consist of some combination of screws, bolts, cables, chains, straps, steel angles, and other steel hardware that transfer seismic loads to structural framing. Positive connections do not rely solely on the frictional resistance produced by the effects of gravity. Frictional resistance between the base of an object and the floor or mechanical friction connections such as C-clamps or thumbscrew clamps are not considered

Earthquake Forces

Keep in mind that although heavy objects are hard to move by hand, their weight (mass) interacts with the shaking (accelerations) of an earthquake to produce large inertial forces. Those forces mostly act sideways to make the object slide or tip, and there are also vertical motions in earthquakes that temporarily "lighten" an object and reduce frictional resistance.

positive connections. The most common nonstructural connection details for wall attachments, floor or ceiling attachments, countertop attachments, and attachments between adjacent items are discussed below.

6.6.2 Typical Wall Attachment Details

Many types of nonstructural items can be anchored, braced, or tethered to an adjacent wall to provide stability in an earthquake. Before installing any anchorage details, however, one should determine whether the wall has adequate structural capacity to support the nonstructural items. The wall element should consist of concrete, masonry, or structural framing members that are securely attached to the structural framing at both the top and bottom of the wall.

Anchorage to Wood or Metal Stud Partition Walls

Any type of attachment hardware or brace should be attached directly to a structural stud, not to a gypsum board or to plaster wall covering. Gypsum board and most other interior wall coverings have little capacity to resist out-of-plane loading, that is, loads perpendicular to the wall. A nail or screw can simply pull out of this type of wall covering during an earthquake, leaving a hole in the wall. Even a toggle bolt can pull through the wall sheathing if the demands are sufficient.

Typical wood and metal stud walls are constructed with vertical studs located at either 16- or 24-inch spacing. Many interior partition walls in non-residential construction extend only to the ceiling line and should not be used to anchor heavy nonstructural items, unless the top of the partition wall is braced to the structure above. Heavy items anchored to unbraced partitions may bring the partitions down with them, if they fall during an earthquake. Partition bracing should consist of diagonal elements of similar size and material as the vertical studs, spaced every few feet, connecting the top of the partition to the structure above. Engineering advice may be needed if the partitions appear questionable.

The structural studs should be located at the start of a project, to confirm that they are within reach of the items to be anchored. In situations where many items must be anchored to a stud wall, it is sometimes advantageous to install a mounting strip first, in order to avoid having to relocate items to line them up with studs. Sometimes referred to as seismic molding, a mounting strip is a horizontal member mounted to the wall and anchored to each stud. The strip should be located at or near the top of the items to be anchored. Furniture or cabinets may then be anchored directly to the mounting strip without regard to stud locations. A mounting strip may be constructed of a structural-grade wood 2x4 or 2x6 or a continuous steel channel or angle. The strip can be finished to have an appropriate architectural

appearance. In fact, horizontal strips a few feet off the floor were often included in older architectural styles and were called chair rails; even today in many settings, such as hotel conference rooms, there are similar architectural features.

In new construction this is typically accommodated by installing "backing plates" directly on the studs, before sheathing is installed. Backing plates are commonly 16 gauge steel plates, runner tracks or studs.

HARDWARE – RECOMMENDED

- Attach steel angle directly to wood studs using a minimum 1/4-inch diameter by 3-inch lag bolt (maximum 3/8-inch lag bolt). Embed the bolt at least 2 inches into the wood stud.
- Attach steel angle to metal studs using #12 sheet-metal screws long enough to penetrate the flange material. Use two screws per connection, located 3 inches apart vertically.
- Attachments for anchoring sheet-metal shelving or cabinets may be made by using a minimum 1/4-inch diameter machine bolt. Where possible, attach the bolt through two layers of material, for example where the top and side or back and side pieces overlap. Otherwise, use an oversized 2-inch diameter by 3/32-inch thick fender washer with the nut on the inside of the cabinet to provide additional strength.
- For seismic molding, use #14 flat-head wood screws, with countersunk heads, with at least 2 inches embedded into the wood stud behind the wall covering. Locate screws along the centerline of the 2x4 or 2x6, and anchor the strip to each stud with maximum spacing of 24 inches. For attachments to the wood molding strip, do not screw or bolt anything within 1-inch of each edge of the wood member.
- Small quick-release safety hooks (carabiners) and nylon cord or straps, are often available at sporting goods stores that carry mountain climbing equipment. Self-drilling screws may be useful, especially for a connection to metal studs. These items may be used for tethering small office equipment.

HARDWARE - NOT RECOMMENDED

- Toggle bolts mounted in gypsum board or plaster are not recommended for any of the details presented here. They may be useful for items weighing only a few pounds.
- Nails have little capacity in tension or withdrawal, i.e., when pulled directly on the head of the nail. Thus, nails are not recommended for any of these details.

Anchorage to Concrete or Masonry Walls

Connections to existing concrete or grouted masonry walls should be made with steel anchor bolts made to insert into walls after they are built. Many types of anchors are available from various vendors, including expansion anchors, sleeve anchors, and epoxy anchors. Since the installation procedures and capacities for these anchors vary widely, it is important to check the local building code or vendor literature for the allowable load capacity and to install the anchors in accordance with the manufacturer's recommendations. Holes into concrete or masonry walls should be drilled with care, in order to avoid cutting any reinforcing steel (rebar). A magnetic device can be used to locate the steel prior to drilling. If rebar is encountered while drilling, stop, and relocate the hole; **do not cut through the reinforcing steel** unless directed by a structural engineer who has examined the specific condition. In buildings with post-tensioned construction, post-tensioning cables must be positively located prior to anchor installation.

The capacity of an anchor bolt in concrete is governed by the strength of the concrete, the bolt diameter, the depth of embedment of the bolt into the concrete, the spacing between adjacent bolts, and the distance to the edge of the concrete. Improper installation can result in a bolt with virtually no capacity. The bolt will have a greatly reduced capacity if it is too near to an edge or too close to an adjacent bolt, or if it has insufficient embedment into the concrete. In order to develop the full capacity of a concrete anchor, as a rule of thumb, the spacing of the bolts should be at least 12 bolt diameters, with a minimum edge distance of 6 diameters. The minimum embedment length is typically 8 bolt diameters. Specific requirements for edge distance, spacing and embedment depth are determined by anchor manufacturers and code requirementsCaution should be used in selecting anchors to ensure that they have been prequalified for seismic applications and are capable of maintaining their strength under repeated cyclic loading including installations in cracked concrete. The most common post-installed anchors are expansion anchors, where part of the shank expands to press against the sides of the hole as the nut is tightened. Recently, large screw anchors have been gaining popularity. Other types of anchors include sleeve anchors and adhesive anchors. Sleeve anchors consist of a threaded sleeve installed directly into the concrete, flush with the concrete surface, and a bolt that is screwed into the sleeve. Sleeve anchors may be advantageous in situations, in which items may be moved frequently. The bolt may be removed, leaving the sleeve flush with the wall (or floor) and without leaving a protruding bolt. Adhesive anchors are inserted into slightly oversized holes with epoxy or polyester resin so that the adhesive will hold the bolt in place. Extreme care is required to ensure that the epoxy components are mixed in the proper proportions within the hole and that dust is removed from it; otherwise the bolt will never reach the manufacturer's rated capacity. Quality control is critical for all post-

installed anchors. Installation by experienced personnel and inspection by professional inspectors is recommended.

HARDWARE AND PROCEDURES – RECOMMENDED

- Do not cut reinforcing steel, tendons, or electrical conduit embedded in concrete or masonry walls. Locate the steel or conduit prior to drilling. There are many types of devices available for locating steel in concrete or masonry. These devices require the user to be familiar with their limitations.
- Follow manufacturer's recommendations for installation. Remove dust from the hole prior to inserting the anchor bolt by using a hand-held vacuum cleaner; or blow the dust out with a bellows or a bulb.
- For anchorage to reinforced concrete walls, expansion anchors are commonly used.
- To check if an anchor is properly installed, test a sample of installed bolts with a proof load or by torque as required by the manufacturers, test reports, or direction by the design professional of record.
- Use galvanized or preferably stainless steel bolts and other hardware in locations where they will be exposed to moisture or weathering.
- Corrosion resistant chains, eyebolts, and quick-release safety hooks can often be found at marine supply stores, hardware stores, or ordered from industrial catalogues. These fasteners may be needed to provide wall anchorage for gas cylinders or other items stored outside or in a damp location.
- For anchors in walls constructed of concrete masonry units, the expansion anchors should be installed only in grouted cells, where the cavity in the masonry unit is filled with grout and reinforcing steel. In order to achieve adequate embedment into the grout, longer bolts may have to be used in concrete masonry unit walls. Through-bolts, where feasible, generally provide the highest capacity and reliability. These are machine bolts that go through the concrete slab and are fastened with nuts and steel plate washers on the underside of the slab. Unreinforced masonry walls, particularly cantilever partition walls, may not have adequate strength to anchor heavy nonstructural items. For light loads, up to 100 pounds, masonry toggle bolts can be used in ungrouted cells.
- For unreinforced masonry walls, engineering assistance is recommended. Published capacities for expansion anchors typically apply to concrete, not to brick. Anchorage to the floor may be a preferable solution in a brick building.
- Anchorage hardware, installation procedures, and code requirements are continually evolving. Some types of bolts may not be appropriate for overhead applications,

vibratory loading, seismic loading, or cracked concrete applications; check with the manufacturer for recommended usage.

HARDWARE AND PROCEDURES - NOT RECOMMENDED

- Adhesive or epoxy anchors are not recommended, unless they are installed by experienced personnel with proper quality control. Unless specifically tested for high temperature applications, adhesive or epoxy anchors should not be used in unconditioned environments, since their strength can be reduced at elevated temperatures.
- Inserts made of lead or plastic placed in holes drilled in concrete or masonry and used with lag screws have very limited capacity and are not recommended.

6.6.3 Typical Floor and Ceiling Attachment Details

For heavy items, anchorage to a concrete floor slab is often preferable to wall anchorage because it avoids the additional seismic load to the wall. Ceiling attachment details are required for many types of piping, ducts, light fixtures, and overhead fans or heaters. The type of detail used in each situation will depend on the structural materials of the floor and ceiling framing.

Anchorage to Wood Framing

Because wood flooring such as1/2-inch plywood or 1/4 to 3/8-inch strip oak flooring typically does not have adequate strength to resist large concentrated forces, floor or ceiling anchorage hardware should be attached directly to the floor or ceiling beams or joists.

HARDWARE AND PROCEDURES - RECOMMENDED

- Locate the floor or ceiling joists prior to beginning work. If wood beams or joists are not situated within a convenient distance, then wood blocking may be used to provide additional anchor locations. Install blocking perpendicular to the joists, using, as a minimum, a member of the same size as the joists. Anchor the blocking with framing clips to the joists at each end. Do not toenail the blocking.
- Wood screws or lag bolts should be used for simple anchorage connections for lighter items. A 1/4-inch diameter by 3-inch lag bolt will be adequate for many types of connections.
- For anchorage of heavier items to the roof or floor, add blocking beneath the anchor location, run A307 bolts through the blocking, and tighten them on the underside with nuts and washers.

HARDWARE AND PROCEDURES - NOT RECOMMENDED

- Do not anchor heavy items directly to wood or plywood floor or roof sheathing, as these materials typically do not have adequate capacity to resist significant out-of-plane loads.
- Nails are not recommended for nonstructural anchorage details.

Anchorage to Steel Framing

Caution should be used in anchoring nonstructural items to structural steel framing. Engineering expertise may be needed to determine whether holes can be drilled through structural steel framing without compromising the integrity of the structural members. There are several types of connection details that do not require holes through the steel framing. In addition, where steel framing is fireproofed, special measures may be needed to restore the fire rating after connections are made.

HARDWARE - RECOMMENDED

- Vendor catalogues of hardware that can be used to provide both vertical and lateral support for piping often include fittings specifically designed for steel framing. While C-clamps are not recommended, there are a variety of other devices that clamp mechanically around the flange of a steel beam or are designed to fit between column flanges. These devices are typically load-rated by the vendors and come in a variety of sizes. Besides bracing piping and ducts, this type of hardware might also be used for bracing or anchoring items like lights or ceiling fans.

Anchorage to Concrete Floor or Roof Slabs

Concrete expansion anchors are the most common type of hardware used to anchor items to a concrete slab on grade or to a structural floor slab. Most manufacturers require a minimum slab thickness on the order of 1.5 times the anchor embedment depth. For heavy loads or concrete slabs less than 4 inches thick, it may be preferable to use through-bolts.

HARDWARE AND PROCEDURES - RECOMMENDED

- Refer to discussion of expansion anchors under concrete wall anchorage details.
- **Do not cut reinforcing steel or tendons in concrete slabs or beams.** Locate the reinforcing steel, post-tensioning tendons, any embedded water pipes, and electrical conduit prior to drilling holes in concrete slabs.

- For anchorage to a concrete foundation pad, slab on grade, or suspended floor, check the drawings for the thickness of the concrete, or perform exploratory investigation to confirm the thickness. While short expansion bolts may be adequate to prevent sliding of squat equipment, longer bolts with greater embedment are generally needed to prevent the combination of sliding and overturning forces for items that are taller than they are wide.
- If equipment is resting on leveling bolts or must be level to allow for proper operation, then vertically slotted connections may be needed to allow for adjustment.

HARDWARE AND PROCEDURES - NOT RECOMMENDED

Anchors that have not been qualified for seismic applications should not be used unless they are specifically justified by a licensed professional and are permitted for use by the authority having jurisdiction.

6.6.4 Typical Shelf or Countertop Attachment Details

If important or essential contents are to be secured, then the shelf or mounting surface should be secured prior to anchoring nonstructural items. While standard desks and office tables are unlikely to overturn, they may slide during an earthquake. Desktop computers and printers can be anchored to the desk by means of hook-and-loop tape such as Velcro or by using various types of security devices designed to prevent theft.

HARDWARE AND PROCEDURES - RECOMMENDED

- Unanchored desks or tables may slide and pull on the electrical cords of office equipment, if the items are anchored to the tabletop. Electrical cords should have adequate slack to allow for movement of unanchored desks or tables.
- Loose shelves should be secured to the wall or to shelf brackets. Wood shelves that rest on wall-mounted brackets may be secured to the brackets with 1/2-inch long wood screws.
- Many types of vendor-supplied anchorage and security devices are available for computer equipment. These may also be adapted for other types of countertop equipment, such as medical or laboratory equipment. Heavy-duty hook-and-loop tape with adhesive backing can be purchased at most hardware and fabric stores and can readily be cut into strips.
- Desktop computer equipment usually consists of several independent components. If items are stacked, then make sure that each component is anchored to the one beneath it and that the bottommost item is anchored to the desk. For tall configurations of

items that do not have to be moved frequently, it may be more advantageous to tie an assembly of components together using nylon strap and then to anchor the base to the desktop.

- For light and nonessential items on shelves or countertops, a 1- to 2-inch lip secured to the edge of the counter or shelf may be adequate to prevent miscellaneous items from falling. In this case, individual items need not be anchored.

6.6.5 Purchasing

In some instances, it is easier to install nonstructural anchorage details for newly purchased equipment than for existing equipment. Many items are available off the shelf or can be special-ordered with seismic attachment provisions from the manufacturer. Some file cabinets come with predrilled holes for floor anchorage and strong latches on the drawers. Installing a strong shelf over the top of a bank of file cabinets that will line a wall or using other architectural ways to provide built-in restraint can be cost-effective and have a non-seismic benefit. Battery racks, industrial storage racks, and computer access floors that meet seismic requirements specified in the building code can be ordered. It is always useful to inquire about the availability of seismic attachment provisions when purchasing new equipment.

6.6.6 Patching, Painting, and Corrosion Protection

Most of the details shown here assume that the nonstructural component in question is situated in a dry, interior location. In these locations, some cosmetic patching and painting may be desirable, primarily for aesthetic reasons.

For basements, roofs, or other exterior locations, it is important to provide adequate protection from weathering and corrosion. If attachment details perforate a roof membrane, then appropriate sealants or localized repair will be needed, in order to avoid roof leakage. If expansion anchors or other steel hardware will be exposed to moist conditions or weathering, then either stainless steel or galvanized hardware should be selected to avoid corrosion and deterioration. Many types of paints and coatings are available that will help retard corrosion. Exterior earthquake protection devices may need periodic maintenance to avoid deterioration.

In cases where a chain, latch, or tether is installed and users must remove and replace some hardware whenever they need to use the item, it may be helpful to select a bright or distinctive paint color as a reminder that the seismic restraint, chain, or hook needs to be refastened.

6.6.7 Safety Precautions

As with any type of construction work, there are safety precautions that must be followed while installing nonstructural attachment details. Employers and the skilled trades must comply with numerous local, state, and federal safety regulations and follow guidelines established for specific trades or industries. The following list is not comprehensive but is a brief list of safety precautions that merit emphasis in connection with the nonstructural attachment details shown here.

PROCEDURES - RECOMMENDED

- The individuals installing seismic mitigation measures should have adequate training and supervision. Office workers or volunteers may not have the necessary background.
- Electrical hazards are present around any equipment supplied with electrical power. See FEMA 413, *Installing Seismic Restraints for Electrical Equipment* (FEMA, 2004) www.fema.gov/library/viewRecord.do?id=1436.
- Mechanical and electrical hazards are present around machinery that is operating. See FEMA 412, *Installing Seismic Restraints for Mechanical Equipment* (FEMA, 2002), www.fema.gov/library/viewRecord.do?id=1557.
- For guidance on bracing ducts and piping, see FEMA 414, *Installing Seismic Restraints for Duct and Pipe* (FEMA, 2004) www.fema.gov/library/viewRecord.do?id=1437.
- All power to energized equipment must be turned off and verified as energized by a qualified electrician
- Drilling holes into metal cabinets containing electrical components or piping may void the equipment warranty, create an electrical safety hazard or damage the equipment. Care should be taken to protect the equipment when drilling holes and that no debris has fallen into energized portions of the equipment.

6.6.8 Electrical Danger Warnings and guidelines

- Only qualified personnel familiar with proper voltage equipment are to perform work described in this set of instructions. Workers must understand the hazards involved in working with or near electrical circuits.
- Perform work only after reading and understanding all of the installation instructions in this manual and the manufacturer's literature.
- Turn off all power-supplying equipment before working on or inside equipment.
- Always use a properly rated voltage sensing device to confirm that the power is off.

- Beware of potential hazards. Wear Personal Protective Equipment as required by NFPA-70E, *Standard for Electrical Safety in the Workplace* (2009), and take adequate safety precautions.
- Replace all devices, doors, and covers before turning on the power to the equipment.
- All activities must be performed by qualified personnel in accordance with local codes.
- Handle equipment carefully and install, operate, and maintain it correctly in order for it to function properly. Neglecting fundamental installation and maintenance requirements may lead to personal injury, as well as damage to electrical equipment or other property.
- Heavy equipment should be stabilized with straps and other tie-downs to reduce the possibility of tipping.
- Spreader bars must be evaluated by the appropriate design professional prior to lifting.
- When lifting, do not pass ropes or cables through lift holes. Use slings with safety hooks or shackles.
- Damaged vent housings can constrict proper air flow and expose the interior of electrical voltage compartments to weather.
- Do not make any modifications to the equipment or operate the system with interlocks and safety barriers removed. Contact the manufacturer's representative for additional instructions if the equipment does not function as described in this manual.
- Complete seismic installation and proper inspection of work prior to enabling the circuit breakers.
- Use out-of-service tags and padlocks when working on equipment. Leave tags in place until the work is completed and the equipment is ready to be put back into service.
- Restore all seismic restraints removed for maintenance to their original installation configuration and torque all bolts and anchors to their proper values.
- Carefully inspect the work area and remove any tools and objects left inside the equipment.
- Remove all tools, lifting assembly, and miscellaneous items left on the equipment prior to enabling the circuit breaker.
- All instructions provided in this manual and by the manufacturer are written with the assumption that the customer has taken the above measures before performing any maintenance or testing

These electrical danger warnings and guidelines were originally developed for FEMA 413; refer to FEMA 412, 413, and 414 for additional warnings regarding the installation of bracing or anchorage details for MEP equipment, ducts, and piping.