THE VOICE OF THE CALIFORNIA REAL ESTATE INSPECTION PROFESSION
Inspector eNews

TECHNICAL BULLETIN
Foundation Framing Connections

August 2009

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Proper connections between the framing of a dwelling and the foundation system are critical. These connections provide the path to transfer building live and dead loads down through the structure to the foundation system where it is dispersed into the soil. The further down the load path you go – the higher the stress on the connections. Baring wood decay or other issues, wood-framing members themselves rarely fail. It is the connections that fail when exposed to high stress conditions. In California, we generally call those "earthquakes."

FRAMING CONNECTIONS ARE CRITICAL

Most of California falls into Seismic Design Category D. A small part of California in the central valley/Modesto area falls into Seismic Design Category C. For Seismic Design Categories D & E, the CBC 2007 requires that positive connections and anchorage be installed between the foundation and the framing system. The installed connections must be sufficient to resist the design loads. When earthquake lateral design forces exceed 150 pounds per foot, the toenail capacity is not taken into account in the load calculations. In that case, additional means must be provided to ensure proper load transfer. This would generally be some sort of structural metal connector, etc.

Where the framing members are not continuous from foundation sill to roof, the members must be properly secured to ensure a continuous load path. Metal fasteners or straps may be required to be installed to ensure a continuous load path.

At the bottom of a braced or shear wall, the attachment of the plate and the floor decking to the floor framing provides the load and shear transfer from the wall and the floor diaphragm to the floor framing below. When nails or lag screws resist shear, they must be sufficiently long enough to penetrate through the sole plate and floor sheathing into the framing member below.

The fastening requirements for wood framed construction are found in CBC 2007 Table 2304.9.1. For full load values, the CBC specifies a minimum fastener penetration into the framing member. When the minimum fastener penetration falls below the values specified in the relevant table, the fastener cannot be taken into consideration when calculating the load capacity of the system.

The CBC requires that all wood studs have full bearing on the sill or plate. While notching a stud over a foundation bolt is a common practice, it is improper. It is impossible to properly nail the stud to the sole or plate if a significant portion of the stud is missing.

The manufacturers installation instructions for preservatively treated (PT) lumber have required hot-dipped galvanized fasteners for a number of years. In practice, those requirements were largely ignored. Starting circa-2002/2003, the EPA forced manufacturers to discontinue the use of arsenic-based chemical treatments. This shift produced some unintended consequences.

The current generation of preservatively treated lumber uses either copper-based or borate-based chemical treatments. The borate-based products are water-soluble and must not be exposed to weather. The borate products are significantly less corrosive than copper-based materials. The copper-based products constitute much of the preservatively treated lumber used. Copper-based preservatively wood is highly corrosive. Where preservatively treated lumber is used, it is critical that appropriate fasteners must be used.

Since the load is cumulative, the further down the load path you go – the higher the forces involved are. The point of highest stress is generally at the connection between the wood framing and the concrete foundation. Imagine the impact on a dwelling if the shear panels and cripple studs are nailed into a PT mudsill using improper fasteners. In a short while, corrosion will compromise these critical connections. We then have a dwelling that is essentially not secured to the foundation. There are some indications that even hot-dipped galvanized may provide insufficient corrosion protection with the copper-based products.

In some multiple story building, double sole plates may be encountered. The second sole plate may have been installed to act as a form for poured-in-place lightweight concrete or gypsum sub-floor material. Where this occurs, it is important to maintain a load path through both plates. In new construction, this is accomplished by nailing the first sole plate and second sole plate with a sufficient number of nails specified by a design professional. In existing construction, it may be necessary to use extra long nails or screws through both plates so that the fastener has enough penetration into the framing member below.

CONNECTIONS AT SILL PLATES

Because shear loads are cumulative as they work their way down a building, they are greatest at the base of a building. Shear loads are transferred from the shear wall into the foundation through the sill plate. Consequently, the sill plate must be attached to the foundation with anchor bolts or side plates. Before the load enters the anchor bolt or side plate, it must successfully pass through the sill plate. Sill plates should be in good condition and free from cracks. If a cracked or split plate is encountered, it should be replaced before proceeding with any retrofit.

In older construction the existing anchor bolts in the sill plate are usually smaller diameter bolts. Washers may or may not be installed. The bolts will generally be spaced much further apart than current requirements. Older bolts may be degraded due to rust/corrosion. Some older buildings pre-date the requirements for bolting of the sill plates to the concrete stem wall. When retrofitting these older foundations, special retrofit anchors must be used to strengthen

the sill plate to foundation connection. Retrofit sill plate anchors are installed in two ways: drilled-in anchors through the sill plate or side plates that connect the sill plate to the foundation concrete or masonry. Side plates are used when there is not enough room to stand a drill motor on top of the sill plate.

ANCHOR BOLT SPACING REQUIREMENTS

A means to positively connect the structure to the foundation is required. The size and spacing requirements for anchor bolts can vary with seismic design category, building height, etc. In engineered designs, the registered design professional may specify bolting requirements that significantly exceed minimum requirements based on the design calculations. The minimum requirement is that bolts be spaced no farther than 6' apart. Every section of the sill plate should have a minimum of two bolts.

ANCHOR BOLT & WASHER SIZE

Per the CBC 2007, the minimum bolt diameter in Seismic Design Category (SDC) D is ½". In SDC E, 5/8" bolts are required. Certain local jurisdictions may require the use 5/8" anchor bolts in all cases. Some local jurisdictions may also require the use of hot-dipped galvanized anchor bolts where PT lumber sills are installed. Where 5/8" bolts are installed, some local jurisdictions may allow the use of non- hot-dipped galvanized anchor bolts with PT sill plates. Refer to the authority having jurisdiction for specific local requirements.

During the 1994 Northridge, CA earthquake, the sill plates secured with older style washers or no washers were found to split or pulled through the anchor bolts. It was found that a square plate washer is far more effective in a creating good connection between the sill plate and the bolt. They also make tightening of expansion anchors easier.

In SDC D & E 3"x3" plate washers are required. These washers are required to be a minimum of .229" thick – that is almost a ¼". These washers may be slotted to allow for centering on the sill. When slotted washers are used, a standard cut washer must also be used on top.

BOLT CLEARANCES TO THE OUTSIDE EDGE OF THE FOUNDATION

Foundation bolts require a minimum edge distance in concrete. Anchor bolts installed with insufficient distance to the outside edge of the foundation wall will fail in earthquakes or other high stress conditions.

When the foundation walls are located slightly out of position, contractors will sometimes "fudge" the wood wall location. They do this by partially overhanging the sill plate at the edge of the foundation wall. When such a condition is encountered, a registered design professional should be consulted. If the wall overhang is severe or the required edge distances are not provided, a special repair or connection may be needed to effectively transfer the shear loads.

PROVIDE PROPER DEPTH OF EMBEDMENT IN THE CONCRETE

To safely resist imposed loads, all anchors need a minimum 7" depth of embedment in the concrete. If an anchor is set too deep, it should be left in place and another anchor installed

nearby. The plate washers and nuts should not be countersunk into the sill plate as this weakens the connection.

INSTALLING RETROFIT ANCHORS

As with new construction, retrofit foundation bolts require a minimum edge distance in concrete. The manufacturer's recommendations will specify the minimum edge distance required for each diameter anchor. In retrofit installations, obstructions may require the hole be drilled at slight angle. It is important that the bottom of the hole still has the minimum edge clearance distance. This is particularly important when using mechanical anchors.

Drilled-in retrofit type anchors come in two basic types: mechanical and adhesive. Adhesive anchors have the advantage of working in lower strength existing concrete. They are more expensive to install than mechanical anchors and require greater quality control during installation. Mechanical wedge anchors are easier to install but generally require greater concrete strength due to the concentration of stress at the expansion clip. When sufficient concrete strength exits, either adhesive or mechanical anchors may be used. Generally the strength of both anchor types in concrete is greater than their strength in the wood sill plate. All anchoring products should be installed per the manufacturer's installation instruction. Always check with manufacturer and the local building official to determine if special inspection is required.

Normally, drilled-in anchors should be installed near the center of the sill plate. This will furnish the minimum required 1-½ bolt diameter edge distance in the wood, For 2 x 6 sill plates, this will generally provide adequate edge distance in the concrete. When edge distance permits, drilled-in anchors can be installed directly through the blocking added for cripple wall strengthening but longer anchors are needed to provide the minimum depth of embedment in the concrete. Longer anchors may also be required when in older construction where the sill plates are actually a full 2" thick as opposed to the 1-5/8" actual thickness found in nominal lumber.

INSTALLING MECHANICAL RETROFIT FOUNDATION ANCHORS

Mechanical anchors attach to the concrete through friction by mechanically expanding or "wedging" against the concrete. This type of anchor is only effective if the concrete is in good shape and the required edge distance is maintained. A proper diameter hole is essential to allow the anchor to properly engage. Generally, the proper hole diameter is the nominal size of the anchor. Sometimes the bolt may not engage properly due to air or powder pockets in the concrete at the bolts expansion wedge. This will be apparent when the bolt cannot be torqued to the required strength. Should this occur, the bolt should be abandoned. A new bolt should be installed nearby in a new hole.

Wedge anchors must be properly torqued per the manufacturers requirements to properly set them in concrete. For sill plate anchors, the range is generally 50-120 ft-lbs. Under-torquing a bolt can result in pullout under stress. Over-torquing the bolt can result in compression/damage to the wood sill plate under the washer. Always follow the manufacturer's recommendation for the required torque and use a calibrated torque wrench.

INSTALLING ADHESIVE RETROFIT FOUNDATION ANCHORS

CAREFULLY CLEAN THE HOLE

Unlike mechanical anchors, adhesive anchors attach to the concrete chemically; they are glued to the concrete. These products usually come in a two-part tube applicator and are readily available. Because the product creates a chemical bond between the anchor rod and the concrete, it is extremely important that the hole be properly drilled and cleaned. This product must adhere directly to the concrete surface. Any residual concrete dust that might be left in the hole after drilling may result in a failed connection. Carefully clean the hole as required by the manufacturer. The hole must be properly brushed and blown out prior to adhesive installation.

The manufacturer's recommendation will show the minimum embedment depths required. When holes are drilled deeper than required, nuts and plate washers should be installed on the mechanical and adhesive anchors before the pass through the sill plate. This will prevent the anchor from sinking too deep into the hole. The adhesives used are expensive. Consistently drilling holes deeper than necessary will result in higher than necessary material costs.

USE ALL-THREADED ROD

Although these products chemically bond to concrete they will NOT chemically bond to the anchor rod (steel). Therefore, threaded rod is required for all adhesive-anchoring systems. This allows the product to engage the threads and create a good mechanical bond to the rod.

COMPLETELY FILL THE HOLE IN THE SILL PLATE WITH ADHESIVE

Most adhesive products require holes in the concrete that are oversized 1/8 inch larger than the all-thread rod diameter. This creates oversized holes in the wood sill. To remedy this, enough adhesive should be placed in the hole to overflow the sill plate once the rod is installed. This will allow the sill plate to immediately engage the anchor rod during an earthquake and allow it to transfer shear forces directly into the rod, thus reducing the chances of the sill plate splitting.

INSTALL ALL-THREAD ROD WITH THE PLATE WASHER AND NUT ATTACHED

The washer and nut should be placed on the rod prior to installing the rod since the adhesive extruding from the top of the sill plate will make it difficult, if not impossible to install the washer and nut at a later time.

WAIT UNTIL FULLY CURED BEFORE TIGHTENING

Adhesive anchor installations will need to cure for several hours before they can be tested. Always check manufacturer's requirements for minimum set and cure time. The time will vary depending on the product used and the temperature.

FOLLOW SAFETY REQUIREMENTS

A final word of caution on the use of adhesive anchors: *you need to protect workers and the people living in the building from the fumes.* Check with the manufacturer to find out which product is appropriate for the use and what precautions will be needed.

INSTALLING SIDE PLATES

When installing these plates, follow the manufacturer's installation instructions carefully. Unless otherwise approved. Lag screws require pre-drilling to avoid splitting the sill plate during seismic loading. Pre-drilling for lag screws is required even with pneumatic or electric wrenches. Care should be taken to not over tighten the lag screws during installation. This will "strip" out the hole. To prevent damage to the hole, never drive the lag screws with a hammer.

Lag screws require two different diameter pre-drill holes. The larger diameter pre-drilled hole is for the solid shank portion of the screw. This hole should be drilled the diameter as the screw itself. The second hole is the pre-drill hole for the threaded portion. This hole must be smaller than the threaded diameter in order for the lag screw to grip the wood.

RETROFIT INTERIOR POST TO GIRDER CONNECTIONS

When seismic retrofitting has been performed, the post connections should include toenail connections. The addition of straps or clips may be necessary when there is no existing connection. Post and column connections need to be sufficient to resist lateral forces and any uplift forces. In general, in an older dwelling the biggest performance improvements will be seen by upgrading the perimeter foundation connections and properly bracing any cripple walls or soft first stories. By themselves, elaborate upgrades to interior post connection will provide only a limited benefit. Generally, the post to beam/girder connections need to be sufficient to resist any lateral forces imposed as well as any uplift forces. Generally, toenail connections at the top and bottom will keep the posts from shifting during an earthquake.

About the author:

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