



WARREN

## Uplift and Shear Restraint Techniques for Residential Structures in Hurricane Wind Zones

*By George Sanford, P.E.*

Hurricane and Tropical Storm strength wind forces can wreak havoc on wood-framed residential structures. One of the primary hazards is the negative pressures which can develop on the exterior building envelope when the structure is subjected to the high encircling winds. These negative pressures act like the suction of a giant vacuum on a dwelling's roof diaphragm, which produces enormous uplift forces throughout the entire structure. The leeward walls are also subjected to negative pressures, while the windward walls take the brunt of the positive wind pressures. The uplift on the roof is caused by what the author dubs "the airplane wing effect". In other words, it is the same phenomenon which occurs when air rushes over the wings of an airplane. This air flow produces negative pressure or aerodynamic "lift" under the wings of the plane, allowing the entire aircraft to take flight. If you've ever seen a Boeing 747 or a U.S. Airforce C-17 Heavy Transport in the air, you know that harnessing this force is truly a miracle of modern technology, allowing huge structures to cruise through the air at high altitudes. Unfortunately, uplift on the roof and throughout the structure of a house during a Hurricane is not considered miraculous, just downright destructive. It can literally tear a house apart. From starter homes well inland, to luxurious beachfront mansions, no house is immune. However, it is interesting to note that the higher the roof of a residence, the higher the wind pressures and uplift forces which develop.



Beachfront structures



A luxurious beachfront home

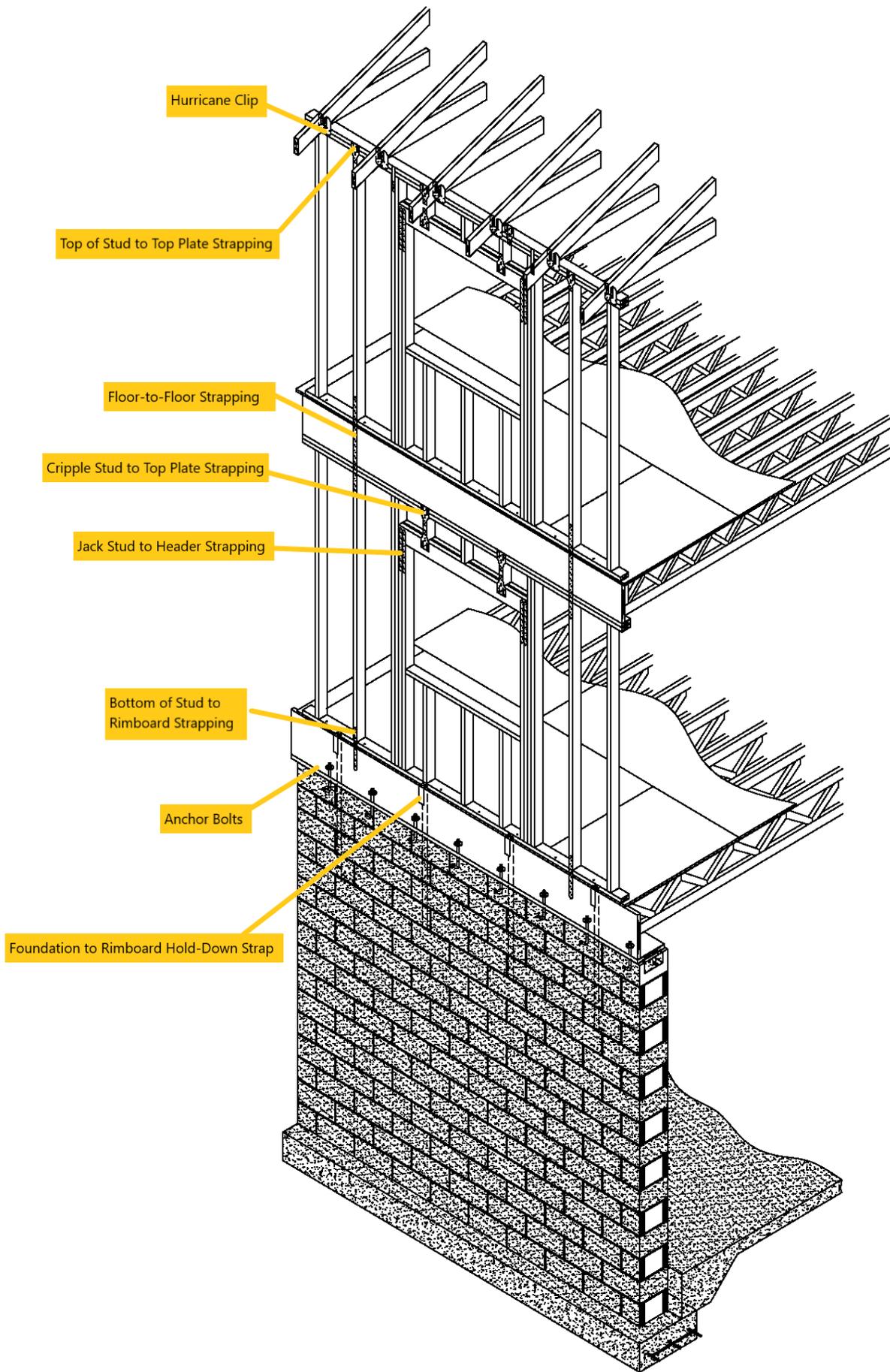


As a result of this destructive force of nature, Architects and Engineers have to build in design features which restrain and withstand these uplift forces for wood-framed structures. This is achieved by providing what is termed a continuous load-path for uplift restraint from the roof all the way down to the foundation. Building Inspections Officials in high wind areas specifically look for these continuous load-path restraint features during inspections of a house's rough framing. Uplift restraint is typically achieved by using nailed-on light-gage galvanized steel connectors. Poly-coated wire-rope cables can also be used. From Hurricane clips on the roof rafters or trusses, to flat strapping on the studs, to heavy-duty hold-down brackets fastened to the bottom of wall corner stud packs and anchored into the foundation, each connector has its own unique purpose. By far the largest supplier of these connectors is the Simpson Strong-Tie Company, but there are several other competitors such as BMD and Quick-Tie Products. In this article, we will discuss each link in the continuous load-path for uplift restraint chain, and the techniques which are used to resist uplift at these links. For (1) and (2) family dwellings, this is covered in the International Residential Code (IRC), latest adopted edition at the time of permitting.

We will now examine the specific links, or "joints" within the wood-framed building envelope structure which require uplift restraint connectors to achieve the continuous load path from top to bottom. See the following CAD detail entitled "Typical Wall Uplift Restraint Connections Detail". Assuming a (2)-story dwelling on a CMU crawlspace or elevated "drive-under" type foundation, the locations of the joints are as follows:

- Hurricane clips attaching the rafters or trusses to the 2nd story exterior wall top plates
- Stud-to-plate tie connectors attaching the 2nd story top plates to the tops of the 1st floor exterior wall studs
- Floor-to-floor flat strapping attaching the bottoms of the 2nd story exterior wall studs, across the 2nd floor rim board, to the tops of the 1st floor exterior wall studs
- Flat strapping attaching the bottoms of the 1st story exterior wall studs to the 1st floor rim boards
- Hold-down straps with hooks embedded into the reinforced and fully-grouted cells of the concrete masonry blockwork (CMU) foundation walls, and attaching to the 1st floor rim boards
- The headers over window and door openings are also subjected to uplift, so (2) of the header jack studs are attached to the headers on either side of each opening. The cripple studs above the headers are also used to attach the headers to the exterior wall double top plates

By making these connections at the joints between the various wood framed wall structural members, the desired continuous load-path for uplift restraint is accomplished. Another structural component which is very important for high wind resistance is the roof and



TYPICAL WALL UPLIFT RESTRAINT  
CONNECTIONS DETAIL  
 ISOMETRIC VIEW



WARREN

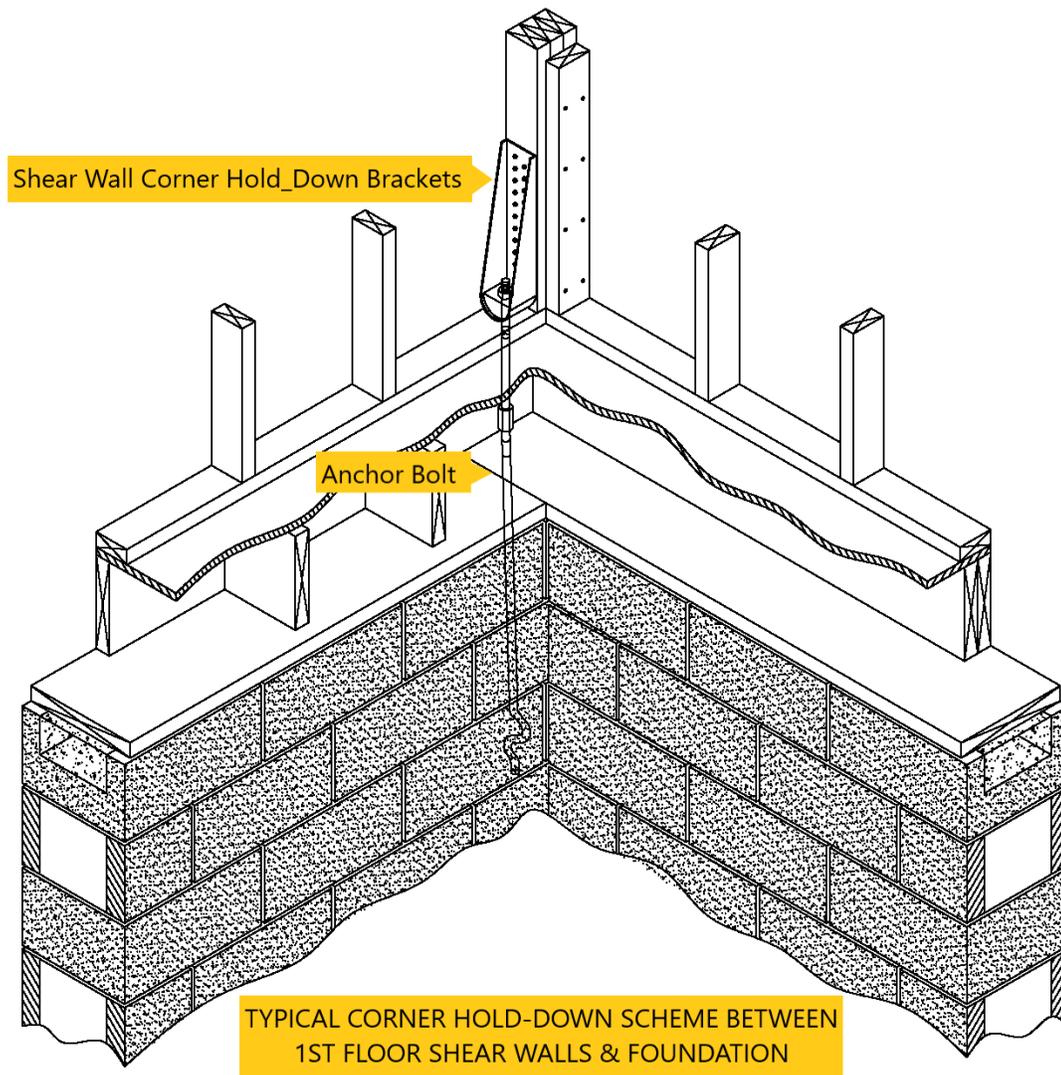
exterior wall sheathing. This sheathing is comprised of 4'x 8' sheets of structural-grade plywood or OSB. The fastening/nailing pattern of this sheathing is critical to uplift restraint, leeward wall negative pressure resistance, resistance of shearing forces imposed on the exterior walls, and overall building envelope structural integrity. Next we will discuss the shearing force phenomenon, and specific methods to restrain it.

High winds have a propensity to push a wood-framed house off its foundation. This causes the floor diaphragms, i.e. framed decks, to impart shear forces into the frame walls of the structure, both interior and exterior. Wall shear can also develop due to the ground motion of a seismic event, when the foundation will move with the shaking of the earth, but the mass and inertia of the wood-framed structure tends to cause the house's superstructure to want to stay where it is. These high shearing loads impart overturning moments on the frame walls. For residential structures governed by the IRC, it is customary to only consider the exterior walls as resisting shear, leading to the name "Shear Walls" for these elements. There are exceptions, however, when interior walls are deemed to be shear walls by the Architect and/or Engineer-of-Record. The shear is resisted by the exterior walls by installing the exterior wall sheathing with the long 8' dimension oriented horizontally, and including flat-wise 2x4 or 2x6 "purlin" blocking at the sheathing panel joints between the studs every 4' vertically. The rigorous nailing of the sheathing to the studs, wall plates, rimboards, and purlins produces very effective shear resistance. Nailing around the perimeters, or "boundaries" of the 4'x8' sheets of sheathing is of particular importance. Note that if one or more interior walls are designated as shear walls, then they are sheathed on both sides with structural plywood/OSB, as opposed to gypsum wall board (GWB), i.e. sheetrock. This is to increase the strength of interior shear walls. The interior of the exterior walls are sheathed with GWB, however, so even the fastening pattern of the sheetrock screws attaching the GWB to the exterior wall studs is rigorous and important.

Another link for shear resistance are the J-type anchor bolts which attach the bottom sill plates to the top of the reinforced, grout-filled CMU foundation. The final link for shear resistance is typically provided by heavy-duty, high load-capacity shear wall hold-down brackets installed at the corners of the exterior walls. See the following CAD detail entitled "Typical Corner Hold-Down Scheme Between 1st Floor Shear Walls & Foundation". The hold-down brackets are attached to triple-stud packs at the building corners by a large arrangement of special wood-screws, then are anchored into the CMU foundation by embedded anchor bolts. They provide a very strong and solid connection to restrain both uplift and shear in the wood-framed structure. This is termed the continuous circuit for shear resistance.

It should be noted that the light-gauge uplift connectors described provide limited shear resistance, as they are prone to tearing in the horizontal direction. Some designers and

manufacturers even recommend the installation of hold-down brackets at the corners of shear walls between floors. This practice is controversial due to the difficulty of installation and the added cost it incurs.



As the readers can see, uplift restraint and shear resistance are very important considerations for Architects, and particularly Structural Design Engineers, for dwellings located in high wind and seismic regions. Fortunately, as discussed herein, these professionals have a large variety of design features available to them which have been proven in-service to resist these destructive forces.



*George Sanford, PE, holds a Bachelor of Science in Mechanical Engineering from North Carolina State University in Raleigh, North Carolina. George has more than 30 years of applied structural engineering experience specializing in residential, commercial, and industrial structures and foundations. Throughout his career, George has designed and analyzed structures, supervised engineers, prepared construction documents (drawings and specifications). He has an in-depth knowledge of many building codes, standards, rules, and regulations including the agencies that govern and provide guidance to building designers such as the International Code Council (ICC) American Society of Civil Engineers (ASCE), Steel Joist Institute (SJI) and the American Iron and Steel Institute (AISI).*