Design Considerations for Sawn Lumber Wood Studs

By Jason A. Partain, P.E.

Today's wood framed structures utilize efficiency and availability of engineered wood products and prefabricated wood systems to supplement sawn lumber framing. A typical wood framed structure may have a prefabricated wood roof truss system, an I-joist or prefabricated wood floor truss system, structural composite lumber beams and headers, and dimensional sawn lumber wall studs. Prefabricated wood systems are designed by specialty engineers and submitted to the engineer of record for review and approval. Engineered wood products are designed using product manufacturer tables, product manufacturer software, or commercial software that includes manufacturer product design data (specifically for beams). Sawn lumber wall stud design may be performed by prescriptive design or by hand calculations, spreadsheet, or commercial software. This article covers design considerations and code required load combinations for sawn lumber wall studs.

Adjustment Factors

One of the key considerations when beginning design of a wood frame structure is the adjustment factors which will affect the allowable design stresses for sawn lumber. Under typical design parameters, wall stud allowable stresses will include adjustment factors for duration of load, beam stability, column stability and nominal stud size. Load distribution due to partial composite action and load sharing is accounted for with a repetitive member factor. Design adjustments for factors such as moisture content are not likely to affect typical wood stud wall design and are outside the scope of this article.

Duration of load factors are provided in Table 2.3.2 of the ANSI/AWC *National Design Specification® for Wood Construction* (NDS®) (AWC, 2005). NDS Table 4A provides stud size factors for reference design values for visually graded dimension lumber of all wood species except Southern Pine. NDS Table 4B provides reference design values for Southern Pine that are already tabulated to include adjustments for size effects.

Out-of-plane wind loads that induce bending in wall studs require consideration be given to beam stability. Based on conventional wall framing, the NDS prescriptive requirements for stability of bending members up to a nominal 2x8 do not require any lateral bracing to use a beam stability factor of 1.0. While this covers most wall studs used in design, wood sheathing attached to the exterior face of studs provides lateral restraint for studs up to 2x10 to qualify for a beam stability factor of 1.0. Additional beam stability requirements are provided in NDS Section 4.4.1 and are outside the scope of this article.

Column stability of a rectangular compression member is analyzed for each axis of a member. A column stability factor of 1.0 applies when a member is supported throughout its length to prevent lateral displacement. Preventing weak axis buckling through lateral restraint of a stud is important for achieving full capacity. Building codes leave judgment of what adequately braces a stud for interpretation by engineers, which has led to varying opinions on bracing materials. Attachment of wood sheathing panels to a stud wall is believed to adequately provide lateral restraint to limit weak axis buckling. Drywall, fiberboard and laminated fibrous boards, such as Thermo-Ply®, are less obvious choices to prevent lateral displacement for studs. According to NDS Commentary Section C3.6.7, experience has shown that these sheathing materials "provide adequate lateral support of the stud across its thickness when properly fastened." Testing also shows that drywall, fiberboard and laminated fibrous boards are capable of resisting weak axis stud buckling when properly attached (Marxhausen, 2009). Test specimens used minimum code requirements to fasten sheathing materials to studs.

A repetitive member factor for allowable bending stress of 1.15 is common to sawn lumber framing used in a system such as sheathed floor joists or sheathed rafters. Conventional software, if using the column design feature to design wall studs, may not apply this factor correctly since a repetitive member factor does not apply to axial capacity. When designing wall studs for out-of-plane wind loads, ANSI/AWC *Special Design Provisions for Wind & Seismic* (SDPWS) (AWC, 2008) allows for an alternative repetitive member factor to calculate allowable bending stress. A repetitive member factor of up to 1.50 can be used, per the SDPWS, when:

> *"Studs are designed for bending, spaced no more than 16-inch on center, covered on the inside with a minimum of ½-inch gypsum wallboard, attached in accordance with minimum building code requirements and sheathed on the exterior with a minimum of ⅜-inch wood structural panel sheathing with all panel joints occurring over studs or blocking and attached using a minimum of 8d common nails spaced at 6-inch on center at panel edges and 12-inch on center at intermediate framing members."*

A study of a common 2x4 wall assembly with wood structural panel sheathing and gypsum wallboard sheathing found that partial composite action and load sharing produced wall strengths greater than predicted by traditional single member design (Polensek, 1976). New repetitive member factors for wood stud wall assemblies

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were developed for use in the design of wall studs with exterior wood structural panel sheathing and interior gypsum wallboard.

Deflection Requirements

The *International Building Code* (IBC) (ICC 2009) provides deflection requirements for walls with flexible or brittle finishes. The IBC lists deflection limits as *l*/120 for walls with flexible finishes and *l*/240 for walls with brittle finishes. Brick veneer anchored to walls is a common exterior finish for many types of structures. There are multiple industry recommendations ranging from *l*/360 to *l*/720. The Brick Industry Association recommends that brick veneer/steel stud wall systems be designed for *l*/600 but does not have similar recommendations for brick veneer/wood stud wall systems. This is, in part, based on the high flexibility and flexural capacity of steel studs in contrast to the rigidity and low flexural strength of brick.

Trestain and Rousseau reported findings of research performed at McMaster University that showed excessive leakage from flexural cracking did not increase system vulnerability. Brick veneer begins cracking at *l*/2000. Deflection limit recommendations do not prevent veneer from cracking, but serve to limit the flexural crack size. Control and management of moisture that enters the system and corrosion resistance of system elements were found to have a more significant impact on system durability than the flexural crack width.

Although no definitive source is available for the deflection limit of wood studs supporting brick veneer, there are avenues to choose the best design requirements. When calculating deflection of the wall system, designers should consider using exterior sheathing attached to studs to create a composite system. Designers should also be aware of any manufacturer requirements for deflection limits on other finish systems. A manufacturer may choose to require a specific deflection limit that if not met could void the warranty of an exterior finish.

Load Combinations

Local, state, and model building codes include provisions for load combinations for both strength design and allowable stress design. These provisions are derived from ASCE 7 *Minimum Design Loads for Buildings and Other Structures* (ASCE). Through experience, engineers may decide to take short cuts when applying load combinations to various structural elements, choosing to design for "worst case" scenarios. For wood design, the duration of load adjustments factors affect the design and may skew what is assumed to be the worst load combination. From ASCE 7-05, applicable load cases to design a wall stud for both bending and axial design loads are:

1) D + L
2) D + (L_r or S or R)
3) D + 0.75L + 0.75(L_r or S or R)
4) D + W
5) D + 0.75W + 0.75L + 0.75(L_r or S or R)

ASCE 7-05 also includes provisions for wind design of structures and structural elements. Main Wind-Force Resisting System (MWFRS) and Component & Cladding (C&C) wind loads as defined in ASCE 7-05 both apply to stud wall design. When analyzing a stud as a wall element, C&C loads should be applied to the stud to check for axial and bending stresses individually. MWFRS loads apply to wall studs when designing for combined axial and bending loads (Douglas and Weeks, 2000). Wind load in each load combination above will vary depending on the use of MWFRS or C&C wind pressures. Depending on geometry of the structure being analyzed, MWFRS can load a stud in both compression and bending in the same load combination.

For multi-story buildings, lower level members supporting multiple floors and a roof see considerable live loads. Live load reductions are allowed based on the supported area of the loaded floor or roof. Reduction factors found in ASCE 7-05 for specific structural elements, such as beams and columns, are not provided for load bearing walls. In typical wood frame construction, the tributary area supported by a wall will not be large enough to allow a reduction in live load.

Computer Analysis

Computer software tools, such as Enercalc and TEDDS, usually include wood design calculations for beams and columns. Using the column design calculation may yield an acceptable design but it does not accurately analyze wall studs. The primary difference is the repetitive member factor and the application of combined loading. An Excel spreadsheet or other custom analysis tool designed specifically for wall studs can yield more accurate and efficient results.

Conclusion

There are several methods available for designing wood members. Some of these methods are well suited for joist and beam design, but not for wood stud design. Because wood design utilizes adjustment factors for duration of load, the worst case loading may not be obvious. Model building codes require designers to consider each load combination for design of a structural element. Stud walls act as both individual elements and as an assembly of elements that support the overall structure. Using both MWFRS and C&C wind loads with the code required load combinations ensures that sawn lumber wood stud walls will continue to be an efficient and reliable structural system.▪

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