APPENDIX B
SUPPLEMENTAL DESIGN DATA

B1. General – This appendix provides supplemental technical data for wall design in accordance with this document, but which is not provided in the reference documents listed in Section 1.6 or in the model building codes. The scope of this appendix covers shear wall resistance values and design information for wall bending members. The objective of this appendix is not to incorporate all the information necessary to complete design of a wall, instead, it is intended to supplement the material design specifications as set forth by the governing building code or specified in Section 1.6 of this Guide.

B2. Shear Wall Resistance Data – Characteristic shear wall values are presented in Tables B1 and B3 for light-frame wood and cold-formed steel, respectively. To compare with design loads, characteristic shear wall values should be modified as specified in Section 4.4.3 of this Guide. The characteristic shear wall values reported in this section were measured experimentally by testing of full-scale shear walls or obtained analytically by interpolating or extrapolating test data using the connection yield theory. The test shear walls were fully restrained against uplift so that the failure mode was predominantly governed by degradation of sheathing fasteners rather than restraint connections of the shear wall assembly. Therefore, to use these values the designer should detail the shear walls to resist the uplift forces or should reduce the wall resistance to account for partial restraint (see Appendix D).

The capacity of shear walls sheathed on opposite faces with the same sheathing materials using identical fastening methods shall be permitted to be calculated as a sum of capacities of each side. The capacity of shear walls sheathed on opposite faces with the same sheathing materials using different fastening methods shall be permitted to be calculated as a capacity of the stronger face or twice the capacity of the weaker face whichever is greater. For wind design, the capacity of shear walls sheathed with structural wood panels on one side and gypsum wallboard panels on the other side shall be permitted to be calculated as a sum of capacities of both sides. If the resistance of gypsum wallboard panels is used in the structural analysis, the gypsum wallboard installation method shall be specified on the shop drawings and the walls shall be inspected upon gypsum wallboard installation for conformance with the wall design.

B2.1 Wood Shear Walls – The characteristic shear wall values (Table B1) are adopted from *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (FEMA Publication 273, BSSC 1997). These values are allowed to be modified using the nail size adjustment factors (Table B2) to determine the unit shear resistance of wood shear walls assembled with pneumatic or box nails. The values are based on wall segments that are fully restrained from overturning.

TABLE B1
CHARACTERISTIC SHEAR VALUES FOR WALLS FRAMED WITH DOUGLAS-FIR-LARCH OR SOUTHERN PINE [1, 2, 3, 4, 5, 6, 7, 8, 9]

Panel Grade	Minimum Nominal Panel Thickness (inches)	Minimum Nail Penetration in Framing (inches)	Nail Size[11] (Common)	Characteristic shear wall values, lb/ft — Nail Spacing at Panel Edges (inches)[10]			
				6	4	3[12]	2[12]
Structural I	5/16	1 1/4	6d	700	1,010	1,130	1,200
	3/8	1 1/2	8d	750	1,080	1,220	1,540
	7/16			815	1,220	1,340	1,590
	15/32			880	1,380	1,550	1,620
	15/32	1 5/8	10d	1,130	1,500	1,700	2,000
C-D, C-C Sheathing, plywood panel siding and other grades covered in US DOC PS1 and PS2.	5/16	1 1/4	6d	650	700	900	1,200
	3/8			680	800	1,000	1,350
	3/8	1 1/2	8d	700	880	1,200	1,500
	7/16			720	900	1,300	1,560
	15/32			820	1,040	1,420	1,600
	15/32	1 5/8	10d	900	1,400	1,500	1,900
	19/32			1,000	1,500	1,620	1,950

[1]Panels applied vertically or horizontally directly to framing and blocked at all edges.
[2]Nominal framing thickness shall be a minimum of 2 inches. Studs are spaced a maximum of 24 inches on center.
[3]Values extrapolated from cyclic testing.
[4]Values can be adjusted for intermediate nail sizes or nail penetration less than specified using the connection yield theory.
[5]Use 80 percent of values for yield strength.
[6]For framing member species other than Douglas-Fir-Larch or Southern Pine the values shall be reduced using the Specific Gravity Adjustment Factor = $[1-(0.5-SG)] \leq 1$, where SG is specific gravity of lumber species.
[7]Minimum nail edge distance of 3/8 inch shall be provided along panel edges.
[8]Maximum allowable aspect ratio of a shear wall segment is 3.5:1. Resistance of wall segments with aspect ratios between 3.5:1 and 2:1 shall be adjusted using the following reduction factor: $0<2b/h<1.0$, where b = segment width and h = segment height.
[9]Shear values are permitted to be adjusted for sheathing nail types using nail size adjustment factors provided in Table B2.
[10]Maximum nail spacing in the panel field is 12 inches.
[11]Common nail diameters: 6d – 0.113 inch, 8d – 0.131, and 10d – 0.148.
[12]3x or greater framing at sheathing joints.

TABLE B2
NAIL SIZE ADJUSTMENT FACTORS FOR USE WITH CHARACTERISTIC SHEAR WALL RESISTANCE VALUES[1]

Nominal Nail Size (penny weight)	Nail Length (inches)	Nail Type: Common[2]	Box[3]	Pneumatic (by diameter in inches)			
				0.092	0.113	0.131	0.148
6d	1-7/8 to 2	1.0	0.8	0.9	1.0	N/A[4]	N/A[4]
8d	2-3/8 to 2-1/2	1.0	0.8	0.5	0.75	1.0	N/A[4]
10d	3	1.0	0.8	N/A[4]	N/A[4]	0.8	1.0

Source: Residential Structural Design Guide, U.S. Department of Housing and Urban Development, Washington D.C., 2000.
[1]The adjustment factors are based on ratios of the single shear nail values in NER-272 (NES, Inc., 1997) and the NDS (AF&PA, 1997) and are applicable only to wood structural panel sheathing on wood-framed walls. Nail size, diameter, and length should be verified with the manufacturer.
[2]Common nail diameters are as follows: 6d (0.113 inch), 8d (0.131 inch), and 10d (0.148 inch).
[3]Box nail diameters are as follows: 6d (0.099 inch), 8d (0.113 inch), and 10d (0.128 inch).
[4]Diameter not applicable to nominal nail size.

B2.2 Light-Gage Steel Shear Walls - The characteristic shear wall values (Table B3) are adopted from *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (FEMA Publication 368, BSSC 2001). Cold-formed steel walls are assembled using self-drilling self-tapping screws and sheathed using structural wood-based panels.

TABLE B3
CHARACTERISTIC SHEAR VALUES FOR WALLS
FRAMED WITH COLD-FORMED STEEL [1, 2, 3, 4, 5, 6, 7, 8]

Panel Sheathing Type	Characteristic shear wall values, lb/ft Nail Spacing at Panel Edges (inches)			
	6	4	3	2
15/32-inch-thick Structural I plywood	780	990	1,465	1,625
7/16-inch-thick oriented strand board	700	915	1,275	1,700

[1]Panels applied vertically or horizontally directly to framing and blocked at all edges.
[2]Studs shall be a minimum 1 5/8 inch by 3 1/2 inch C-section with 3/8 inch return lip. The studs shall be capped on both ends using track section measured minimum 1 1/4 inch by 3 1/2 inch.
[3]Wall studs and track shall be made of a minimum 33 mil (20 gage) steel with a minimum galvanized coating of G 60 in accordance with ASTM A 653 or equivalent.
[4]Framing screws shall be minimum 5/8-inch-long No. 8 with wafer head. Sheathing screws shall be a minimum 1-inch-long No. 8 with bugle head with a minimum head diameter of 0.292 inches.
[5]Minimum fastener edge distance of 3/8 inch shall be provided along panel edges.
[6]Studs are spaced a maximum of 24 inches on center.
[7]Maximum fastener spacing in the panel field is 12 inches.
[8]Screws extend through the steel member a minimum of three exposed threads.

B3. Repetitive Member Factors and Composite Action Factors – The repetitive member factors and composite action factors set forth in this section are only applicable to the design of bending members consisting of an assembly of dimension lumber as specified.

B3.1 Repetitive Member Factors – When three or more parallel solid-sawn wood members are spaced a maximum of 24 inches on center and connected with structural sheathing or other load distributing elements, they comprise a structural system with more bending capacity than the sum of the single members acting individually. Because the nominal design values tabulated in the NDS are based on performance of individual members, an increase in allowable stress is permitted to account for load redistribution between repetitive members. System assembly tests support the range of repetitive member factors shown in Table B4 for the specified design applications. With the exception of the 1.15 repetitive member factor, the NDS does not currently recognize the values in Table B4. Therefore, the values in Table B4 are provided for use by the designer as an alternative method based on various sources of technical information including standards, code recognized guidelines, and research studies. For more information on repetitive member effects and composite action, consult the references provided in Section B3.4.

TABLE B4
REPETITIVE MEMBER FACTORS FOR USE WITH DIMENSION LUMBER[1, 2, 3]

Application	Recommended C_r Value	References (Section 1.6 or D3.3)
Two adjacent members sharing load[4]	1.1 to 1.2	AF&PA,1996 HUD, 1999
Three adjacent members sharing load[4]	1.2 to 1.3	ASAE, 1997
Four or more adjacent members sharing load[4]	1.3 to 1.4	ASAE, 1997
Three or more members spaced not more than 24 inches on center with suitable surfacing to distribute loads to adjacent members (i.e., decking, panels, boards, etc.)[5]	1.15	NDS, 1997
Wall framing (studs) of three or more members spaced not more than 16 inches on center with minimum 3/8-inch-thick wood structural panel sheathing on one side and 1/2-inch thick gypsum board on the other side subjected to wind pressure[6]	1.5–2x4 or smaller 1.35–2x6 1.25–2x8 1.2–2x10	AF&PA, 1996 SBCCI, 1999 Polensek, 1975

Source: Residential Structural Design Guide, U.S. Department of Housing and Urban Development, Washington D.C., 2000.

[1] Factors shall be used to determine adjusted allowable bending stress.

[2] NDS recommends a C_r value of 1.15 only as shown in the table. The other values in the table were obtained from various codes, standards, and research reports referenced in Section B3.4 of this Appendix.

[3] Dimension lumber bending members are to be parallel in orientation to each other, continuous (i.e., not spliced), and of the same species, grade, and size. The applicable sizes of dimension lumber range from 2x4 to 2x12.

[4] C_r values are given as a range and are applicable to built-up columns and beams formed of continuous members with the strong-axis of all members oriented identically. In general, a larger value of C_r should be used for dimension lumber materials that have a greater variability in strength (i.e., the more variability in strength of individual members the greater the benefit realized in forming a repetitive member system relative to the individual member strength). For example, a two-ply built-up member of No. 2 grade (visually graded) dimension lumber may qualify for use of a C_r value of 1.2 whereas a two-ply member of No. 1 dense mechanically graded lumber may qualify for a C_r value of 1.1. The individual members should be adequately attached to one another such that the individual members act as a unit (i.e., all members deflect equally) in resisting the bending load.

[5] Refer to the NDS and the NDS Commentary for additional guidance on the use of the 1.15 repetitive member factor.

[6] The C_r values are based on wood structural panel attachment to wall framing using 8d common nails spaced at 12 inches on center. For fasteners of a smaller diameter, multiply the C_r values by the ratio of the nail diameter to that of an 8d common nail (0.131 inch diameter). The reduction factor applied to C_r need not be less than 0.75 and the resulting value of C_r should not be adjusted to less than 1.15. Doubling the nailing (i.e., decreasing the fastener spacing by one-half) can increase the C_r value by 16 percent.

B3.2 Header System Effect Factors – The system effect factors for header systems discussed in this section include a combination of repetitive member (load sharing) effect and composite action effect. This appendix considers a header consisting of double members to be a repetitive member system; therefore, a repetitive member factor, C_r, of 1.1 to 1.2 is applicable (see Table B4). Headers are generally designed to support all loads that are within the tributary length of the header including loads from upper stories and roof. However, typical platform construction uses a double top plate above the header that creates a composite member with resistance greater than the resistance of the individual header. When an upper story is supported, a floor band joist and sole plate of the wall above also resist the load and reduce the forces in the header. Testing results (HUD, 1999) show that a repetitive member factor is valid for headers constructed of only two members as shown in Table B4 and that additional composite effects produce large increases in capacity when the header is overlaid by a double top plate, band joist and sole plate. Consequently, an overall system factor of 1.8 was found to be a simple, conservative design solution (Table B5). That system factor is applicable to the allowable bending stress value, F_b', of the header members only. The above adjustment factor is not currently recognized in the NDS and should be used at the designer's discretion as an alternative means and method of design.

TABLE B5
HEADER SYSTEM EFFECT FACTORS

Header Type and Application[1]	Recommended C_r Value[2]
2x10 double header of No. 2 Spruce-Pine-Fir	1.30 [3]
Header with double top plate, 2x10 floor band joist, and sole plate of wall located directly above.	1.8 [4]

Source: Residential Structural Design Guide, U.S. Department of Housing and Urban Development, Washington D.C., 2000.
[1]For other applications and lumber sizes or grades, refer to the C_r factors in Table B3.
[2]Apply C_r in lieu of factors in Table B3 to determine adjusted allowable bending stress.
[3]Use C_r = 1.35 when the header is overlaid by a minimum 2x4 double top plate without splices. This factor is higher than the factors recommended in Table B4 because it is based on testing of the specific system configuration. The factors in Table B4 are recommended for a wide range of applications and represent conservative estimates of the actual system response.
[4]Includes repetitive and composite effect of other members in the specified system.

B3.3 Horizontal Shear Factor – The horizontal shear factor, C_H, in the NDS was developed based on the assumption that shear design values for dimension lumber, F_v, did not incorporate a reduction for end splitting of lumber. During recent re-evaluation of this assumption, the ASTM D7 Task Committee assigned to this topic found that shear design values did incorporate a reduction for the effect of end splitting. Therefore, a C_H factor of 2.0 should be used with the 1997 NDS provisions (and previous editions of NDS) until this error is corrected in the future NDS editions. The C_H factor applies to parallel-to-grain shear stress, F_v, in bending members.

B3.4 References

AF&PA, National Design Specification for Wood Construction, American Forest and Paper Association, Washington DC, 1997.

AF&PA, Wood Frame Construction Manual – SBC High Wind Edition, American Forest and Paper Association, Washington DC, 1996.

ASAE, Design Requirements and Bending Properties for Mechanically Laminated Columns (EP 559), American Society of Agricultural Engineers, St. Joseph, MI, 1997.

BSSC, NEHRP Guidelines for the Seismic Rehabilitation of Buildings (FEMA-273), Building Seismic Safety Council, Washington, DC, 1997.

BSSC, NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures (FEMA-368), Building Seismic Safety Council, Washington, DC, 2001.

Bonnicksen, L.W. and Suddarth, S.K., Structural Reliability Analysis of Wood Load Sharing Systems, Paper No. 82, American Society of Testing and Materials, Fifth National Meeting, Philadelphia, Pennsylvania, 1965.

Douglas, B.K. and Line, P., System Effects in Wood Assemblies, Proceedings of the International Wood Engineering Conference, New Orleans, LA, 1996.

FPRS, Wall & Floor Systems: Design and Performance of Light Frame Structures, Proceedings 7317, Forest Products Research Society, Madison, WI, 1983.

HUD, System Performance of Wood Header Assemblies, prepared by the NAHB Research Center, Inc., for the U.S. Department of Housing and Urban Development, Washington, DC, 1999.

NAHBRF, Stress and Deflection Reduction in 2x4 Studs Spaced 24 Inches on Center Due to the Addition of Interior and Exterior Surfacings, NAHB Research Foundation, Rockville, MD, July 1974.

National Evaluation Service, Inc. Report No. NER-272, Power Driven Staples, Nails, and Allied Fasteners for Use in All Types of Building Construction, Council of American Building Officials, Falls Church, VA, 1996.

Polensek, A., Rational Design Procedure for Wood Stud Walls under Bending and Compression Loads, Forest Research Laboratory, Oregon State University, September 1975.

Rosowsky, D. and Ellingwood, B., Reliability of Wood Systems Subjected to Stochastic Live Loads, Wood and Fiber Science, Society of Wood Science and Technology, Madison, WI, 1992.

SBCCI, Standard Building Code, Southern Building Code Congress International, Birmingham, AL, 1999.

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Wolfe, R.W., Structural Performance of Light-Frame Truss-Roof Assemblies, Proceedings of the International Wood Engineering Conference, Vol. 3, Omnipress, Madison, WI, 1996.