LRFD versus ASD for Wood Design – Load Combinations Lead to Efficiencies

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Introduction

Load and resistance factor design (LRFD) for wood was recently incorporated in the American Forest & Paper Association's (AF&PA) *2005 National Design Specification® (NDS®) for Wood Construction*. Appendix N of the *NDS* refers to the American Society of Civil Engineer's (ASCE) *Minimum Design Loads for Buildings and Other Structures, ASCE 7-02* (2002) for LRFD load combinations. Several case studies have been conducted to compare the LRFD methodology to the allowable stress design (ASD) methodology for wood. These case studies indicate that load combinations, as permitted by LRFD, can lead to greater efficiencies in wood design. For multi-story structures, where components such as load-bearing studs and headers are designed for multiple transient live loads, this could be significant.

Case Studies

Case studies comparing designs using LRFD methodology to those using ASD procedures as prescribed in the *NDS* indicate similar results for beams and connections with live to dead load ratios of 3:1. Showalter et al. (1998) indicated that efficiencies could be achieved for certain designs using LRFD versus ASD, due primarily to load factoring per *ASCE 7-98* (1998) (see also Taylor 2001 and 2002). Those same case studies evaluated per *ASCE 7-02* show that those efficiencies are also possible with the new standard.

Load Combinations

Table 1 outlines ASD and LRFD loads and load reductions from *ASCE 7-02* (2002). For ASD, applicable load duration factors are taken from *NDS* Table 2.3.2. Note that ASCE 7-02 allows a 25-percent reduction in transient loads used in ASD combinations. The 25-percent reduction as shown in column 6 of **Table 1** was accounted for in this load combination comparison.

For LRFD loads and load factors, the *2005 NDS Appendix N* (Table N3) outlines load combinations and time effect factors consistent with *ASCE 7-02*. For comparison purposes, load combinations most common to multi-story structures are shown in **Table 1**.

Only gravity loads including dead (D), occupancy live (L), snow (S), and roof live or construction (L_r) are evaluated in this table. Due to the varied treatment of seismic loads in combination with other loads in the various building codes, they have been omitted from this comparison. With respect to wind loads, Douglas and Weeks (2001) showed that components and assemblies that receive wind directly and as part of the main wind force resisting system (MWFRS) should be checked for MWFRS and components and cladding wind loads independently. For components that must be designed for wind loads, the load case of wind acting alone will often control. Due to the multiple checks required for wind load analysis, combinations regarding wind loads were also omitted. Less common loads such as

Table 1. — LRFD/ASD load combination comparisons.

	Allowable stress design							Load and resistance factor design							
	Load types				ASCE 7 load factor			Load types							
	D	L	L_r	S		C_D	Load/C_D	D	L	L_r	S	λ	Load/λ	LRFD load/ ASD load	LRFD/ (2.16*ASD)
1	1				1	0.9	22.22	1.4				0.6	46.67	2.10	0.97
2	1	1			1	1	60.00	1.2	1.6			0.8	110.00	1.83	0.85
3	1		1		1	1.25	32.00	1.2		1.6		0.8	70.00	2.19	1.01
4	1			1	1	1.15	43.48	1.2			1.6	0.8	90.00	2.07	0.96
5	1	1		1	0.75	1.15	63.04	1.2	1.6		0.5	0.8	128.75	2.04	0.95
6	1	1		1	0.75	1.15	63.04	1.2	0.5		1.6	0.8	115.00	1.82	0.84
7	1	1	1		0.75	1.25	52.00	1.2	1.6	0.5		0.8	122.50	2.36	1.09
8	1	1	1		0.75	1.25	52.00	1.2	0.5	1.6		0.8	95.00	1.83	0.85

D = dead, L = floor live, L_r = roof live, S = snow.
D = 20 psf, L = 40 psf, L_r = 20 psf, S = 30 psf.

ice, fluid pressure, flood, earth pressure, rain, and self-straining forces were also not incorporated here.

Note that *ASCE 7-02* contains an exception permitting a load factor on L in combinations shown in this article to be 0.5 for all occupancies in which L is less than or equal to 100 psf, with the exception of garages or areas occupied as places of public assembly.

Eight load combinations are shown in **Table 1** combining dead, floor live, construction, and snow loads. Load magnitudes commonly specified in building codes are used to calculate a total load, which is adjusted by applicable reduction factors for ASD or load factors for LRFD. Note that results provided in **Table 1** would differ for other load magnitudes. The load duration factor, C_D, for ASD and time effect factor, λ, for LRFD are divided out of the total load to determine a comparable strength limit state. The second column from the right shows the ratio of LRFD/ASD adjusted total loads. This ratio is then divided by the format conversion factor, K_F, (see *NDS* Appendix N, Table N1) of 2.16 to allow relative comparison of these two methodologies (see ASTM D5457 (2004) for details). A ratio less than one indicates that LRFD should provide a more efficient design should that load combination control. Conversely, a ratio greater than unity indicates a benefit using ASD loads.

Note that a deflection controlled member should be identical with ASD versus LRFD, since unfactored loads are used for deflection calculations. Note also that compression perpendicular to grain uses a different K_F factor, so this analysis would show different results for bearing controlled applications.

Column buckling and beam buckling are not explicitly addressed in **Table 1**, since in those cases it is not appropriate to divide loads directly by C_D or λ. By extension, many cases of combined loading are not completely addressed by the simplified treatment in **Table 1** (since most combined loading scenarios involve column buckling and/or beam buckling).

Table 2. — LRFD/ASD load combination comparisons for multiple stories.

	Roof live load (psf)	Ground snow load (psf)		
		30	50	70
Roof only	1.01	0.96	0.99	1.01
Roof and one floor	1.06	0.93	0.93	0.99
Roof and two floors	1.17	1.04	0.97	0.92

Results

As noted in the discussion of case studies above, efficiencies for structural members carrying multiple transient loads (roof live and occupancy) are possible using LRFD versus ASD. As shown in **Table 1**, row 5 would show a 5-percent benefit using LRFD versus ASD. Note that rows 5 and 6 compare dead, occupancy live, and snow load combinations. Row 5 controls for this combination. Examples of this would be headers and studs on the first floor of multi-story buildings. These members will typically carry snow and occupancy live loads.

Table 2 further compares load combinations using the same approach used to develop **Table 1**. However, dead, occupancy live, and snow loads are varied to correspond to multi-story structures. Note that with a few exceptions, LRFD will provide efficiencies due to load factoring.

ASD or LRFD?

The question is often asked, "Why switch to LRFD?" The answer really lies with the designer. The wood industry now has provided a dual format *NDS* to give the user the option of using either methodology as transparently as possible (Line et al. 2004). Universities have predominately been teaching LRFD for the last decade to engineering students, so young designers may have a certain comfort level with LRFD.

One benefit of LRFD is the convenient use of common load sets regardless of the structural materials used. When designing hybrid structures involving wood and other materials; the designer now can use one set of loads for LRFD, instead of switching load sets part way through the structure as required by a structural material change that might have an LRFD or ASD basis. Most structural materials now have the availability of resistance values and design processes on an LRFD basis. However with LRFD, since deflection analysis still requires unfactored loads, both factored and unfactored load sets will be required to provide both factored and unfactored load paths through the entire structure. The bottom line is that the designer can choose the methodology that best suits his or her needs. LRFD makes the design of structures using multiple materials more convenient.

Summary

Load factors can contribute significantly to differences in design results using LRFD versus ASD. In many cases, more economical designs result using LRFD procedures. The underlying premise of load factoring is to move more of the safety factor, or reliability, to the loads side, since more information is available on loads today. It is reasonable to expect that more efficiency in the design process results from this knowledge.

Designers of multi-story wood-frame buildings might consider the LRFD approach where multiple transient live loads could result in significant efficiencies. For applications with numerous structural elements, such as headers, this could result in substantial savings.

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