Engineer's Notebook

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Wood Design

Making the LRFD Leap

By Jerod G. Johnson, Ph.D., S.E.

If your office and its culture are consistent with most structural design firms, you probably embraced the load and resistance factor design (LRFD) approach for reinforced concrete years or even decades ago. For many, working stress design for concrete is a totally foreign concept, while LRFD 'strength' design is what you probably learned in school and practice to this day.

In recent years, the push to LRFD has been embraced by many for the design of steel and masonry systems. While allowable stress design (ASD) methods are still acceptable, the perception is that the majority of engineers use LRFD for concrete, masonry and steel systems. This brings us to wood. ASD has been the basis for engineering wood systems for decades. Textbooks, codes and even the design values listed in technical catalogs of proprietary fasteners and hardware reflect the ASD approach. However, provisions for LRFD design in wood have gradually become more predominant, and it may be only a matter of time before ASD methods are relegated to appendices while LRFD becomes the primary basis of design.

The adoption of LRFD methods for wood has a history not unlike its concrete, masonry and steel counterparts. The 2005 version of the *National Design Specification® (NDS®) for Wood Construction* lists adjustment factors and other values enabling the use of LRFD with the strength design load combinations of ASCE 7. Interestingly enough, the LRFD adjustment factors are listed as the last tables in the last appendix of NDS 2005. Elsewhere, references to LRFD can be found in the "Applicability of Adjustment Factors…" within the main body of the code (e.g., Table 4.3.1). Aside from this, NDS 2005 does little to embrace the LRFD methodology. On the other hand, NDS 2012 has made a major LRFD leap by placing the LRFD adjustment factors in Chapter 2 (page 12).

Times are changing, and little by little the LRFD approach is becoming more mainstream for wood design. Breyer's *Design of Wood Structures* has been a premier text for wood design for many years. The most current (sixth) edition has been re-titled *Design of Wood Structures ASD/LRFD*. At nearly double the size of earlier editions, this text contains side-by-side instruction, examples, and theory of both ASD and LRFD methods for wood design.

NDS 2012 lists the LRFD adjustment factors (K_F), resistance factors (ϕ) and time effect factors (λ) in both the body of the code and the appendices. However, NDS 2012 is still structured in a manner reflecting ASD theory; the listed design values (e.g., F_b, F_c, F_v, etc.) all reflect allowable stresses. Even so, it should be noted that this information is the product of decades of research in the development of LRFD methods for wood.

As an example, consider a simple (single) 2x8 purlin. Once we agree that moisture, temperature, flat use, incision, and repetitive use factors are not applicable (each having a value of 1.0) and that the beam is laterally supported (C_L=1.0), the adjusted design value for bending (following ASD methods) is calculated as:

$$F'_b = F_b C_D C_F$$

For this, the load duration factor (C_D) is predicated by the shortest duration load for a particular combination and the size factor (C_F) is taken from Table 4A of the NDS code (1.2 for this example).

Now consider the same scenario, but follow the LRFD approach. In accordance with the NDS provisions, the adjusted value for bending becomes:

$$F'_b = F_b C_F K_F \phi_b \lambda$$

While the similarities are apparent, you may notice that the C_D factor has been removed and replaced by the λ factor, which accounts for the time effect associated with each of the load combinations for strength design. As you might expect, the value for λ is smaller for sustained loads and larger for transient loads. The value ranges from 0.6 to 1.25 depending on the load combination and the nature of load (e.g., impact live loads vs. storage live loads). The ϕ_b factor is not unlike that used for steel and concrete, having a value of 0.85, while the K_F factor reflects a significant adjustment having a value of 2.54 for the bending design herein discussed. This is the primary variable for adapting the long-held ASD approach to the LRFD approach. Size factor (C_F) and primary design value (F_b) remain unchanged between the ASD and LRFD methods.

Now consider the same 2x8 member and assume #2 DF-L. From NDS, this has F_b = 900 psi. If the controlling load is D+L, the C_D factor is 1.0 and the adjusted design value for allowable stress becomes F'_b = 1,080 psi … quite simple. If we are using LRFD, the value for λ is 0.8 (assuming normal occupancy) and the adjusted nominal design value becomes F'_b = 1,865 psi. Comparison of design values shows a general consistency to the comparison of the ASD (1.0D + 1.0L) and LRFD (1.2D + 1.6L) load combinations, depending on the ratio of live load to dead load. Hence, LRFD yields similar if not identical sizes of wood members as ASD, at least for this example. However, there are still challenges with making the LRFD leap, such as determining how to adapt all of the 'allowable' design values listed in catalogs of fastening hardware, engineered wood products and software.

Admittedly, LRFD requires a few more variables, a little more calculation and perhaps a bit more effort, but it is a step toward a unified (and arguably more reliable) design approach for the four primary materials of construction. Whether you or your office should embrace LRFD for wood is still a matter of choice, but may eventually become only a matter of time.▪

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