Avoiding **Mixed Messages** in Specifying Joist Design Loads

BY JOSEPH J. POTE, P.E.

As load combinations have grown more complex, so have joist manufacturers' needs for load data.

WE ARE ALL SOMETIMES GUILTY of sending mixed messages, despite our intent to provide clear communication. In both my personal and professional life, I am sometimes dismayed to realize how a simple comment may be interpreted completely different from my intent.

As an active participant in the Steel Joist Institute (SJI), I sometimes have the same sense—that a particular specification wording that sounded perfectly reasonable during committee discussions was somehow published in a final form that may send very mixed and confusing messages to most readers. The topic of load specifications and load combinations is one such area where the SJI *42nd Edition Standard Specifications, Load Tables and Weight Tables for Steel Joists and Joist Girders* seems to fall short of providing clear direction, and instead sends mixed and confusing messages.

For example, the two following quotes are from the K-Series Joist Specification:

➜ From Section 4.1 (Method): "When special loads are specified and the specifying professional does not provide the load combinations, the provisions of ASCE 7, '*Minimum Design Loads for Buildings and Other Structures*' shall be used for LRFD and ASD load combinations."

➜ From Section 5.11 (Uplift): "Where uplift forces due to wind are a design requirement, these forces must be indicated on the contract drawings in terms of NET uplift in pounds per square foot (Pascals). The contract documents shall indicate if the net uplift is based upon LRFD or ASD."

Huh? What did that say? On the one hand, in Section 5.11 there is clear indication that the specifying professional must pre-combine the loads for the joist manufacturer, managing any required load factors (LRFD), or load combination reduction factors (ASD), and present a total (factored) load for the joist manufacturer to use in design. However, in Section 4.1, we seemingly contradict ourselves by indicating that the specifying professional is expected to provide load combinations, and by stating what load combinations the joist manufacturer is to use in the absence of any specified load combinations.

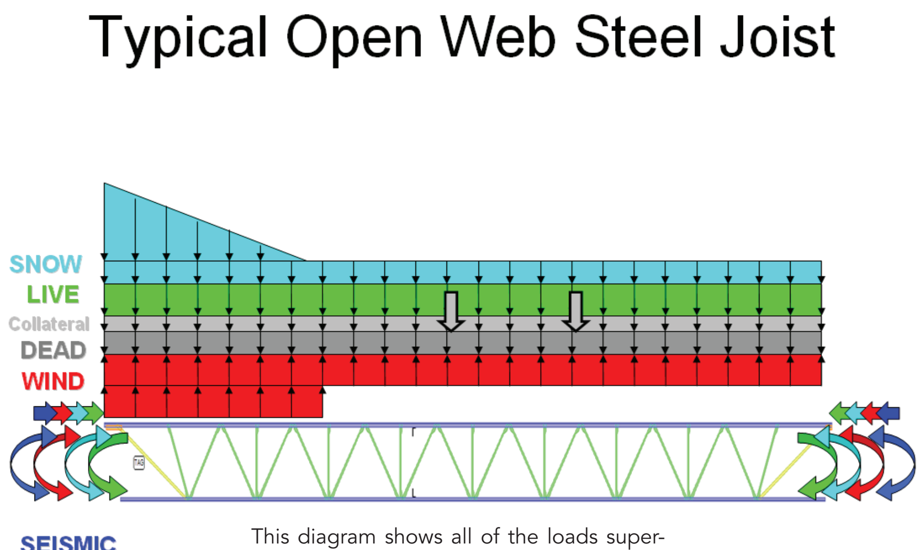
As I read those two quotes from the viewpoint of a specifying professional seeking guidance on how to specify loads for joists, I can almost see the puzzled expression and hear the unspoken question: "If I am supposed to pre-combine and pre-factor all of the loads for the joist manufacturer, then why is the joist manufacturer concerned about what load combinations to use?" It seems to not make much sense.

And yet, to the professionals participating in the SJI committees that develop and maintain these specifications, it made perfect sense at the time it was drafted and reviewed. Now, granted, the SJI *Code of Standard Practice* does a lot to help clean this up and better explain expectations. But I personally think we may have still, unintentionally, left things a little murky, which is the reason for this article. So, what was the SJI intent and why did the final wording result in these seemingly conflicting messages?

The answer is rooted in SJI's trying to provide direction in the midst of a rapidly changing building design and construction industry. A few years ago, when the building codes were far simpler with mostly uniform loading on roofs and floors, most steel joists were pre-designed by the manufacturer, with an array of top chord, bottom chord, end web, and mid-web sizes tabulated for each standard joist size. When a particular joist size and length were specified, the joist engineering technician looked up the appropriate member sizes in a table and filled in the blanks on a standard shop order form used by the production department to manufacture the joist.

At that time, the primary role of the SJI was to provide standard load tables on which each manufacturer based its standard joist designs. The specifying professional could select a joist from the standard load tables with confidence that the joist supplied by any SJI manufacturer would adequately support the tabulated design loads.

Today's building design and construction industry is quite different. Building codes have become significantly more complex. With snow drift, strip wind uplift, and mechanical equipment, applied loads are rarely uniform across the entire roof or floor. With light, unballasted roof systems, much higher design wind loads, and more conservative wind and dead load combinations, net uplift design loads are required on virtually every roof, and likely to control material selections for some joist components. With higher lateral design loads, both wind and seismic, and the elimination of the ⅓ increase in allowable stress, load combinations that include axial loads and end moments are a potentially controlling load condition for a high percentage of joists. With increasingly complex load combinations, for both ASD and LRFD, many joists must be designed based on multiple potentially controlling load combinations. Often the material selections of different structural components (top chord, bottom chord, and various web members) of the same joist are controlled by completely different load combinations.



This diagram shows all of the loads superimposed for a given joist loading condition.

At the same time, the steel joist industry has responded by becoming more sophisticated in its design tools. The advance of personal computers has allowed us to streamline design processes and to better optimize material use. We have developed methods for varying web material sizes at different locations within the joist as the forces change, so as to better optimize the placement of steel while still designing to support the specified design loads. We have developed systems that allow us to manage multiple load categories assembled into multiple load combinations, for consideration in our material selection routines.

As a result, today, virtually every single joist produced is a custom-designed joist manufactured for use in a specific location on a specific project. Even "standard" joists, selected by the specifying professional from the SJI Standard Load Tables, are designed on a per-mark basis to support the tabulated load requirements, per SJI-approved design procedures.

We find ourselves with a rich history of standard joist designs based on simple uniform gravity loads, which still serve a useful function in today's building design and construction industry. Yet our design systems and processes have evolved to the point that virtually every joist is truly a custom design, and we can adeptly manage the special loading conditions that are often required by today's design standards. Thus, joist manufacturers must respond equally well to a project with a simple mezzanine floor with all standard joists requiring simple uniform gravity loads, or a project with complex roof loading, snow drifts, strip uplifts, lateral load resisting frames in one direction, deck diaphragm and shear wall system with high joist top chord axial loads in the other direction, and a multitude of mechanical, electrical, plumbing, and sprinkler systems to be threaded through our web openings and supported by our joists.

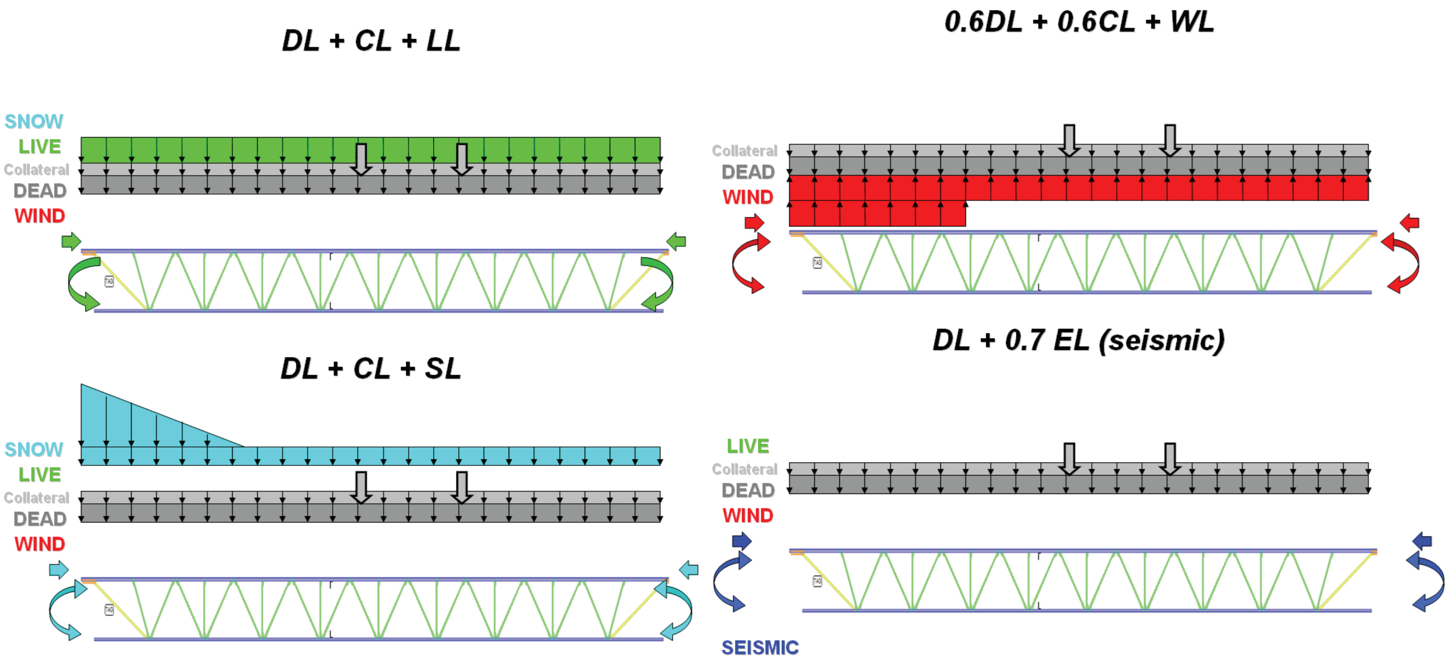
So, this seemingly contradictory wording, sending possible mixed messages, is a result of the SJI attempting to communicate with a wide audience of design professionals with a wide range of building design requirements. What manufacturers really need to correctly design joists is clearly defined joist loading requirements.

Sounds easy enough, right? Yet, I have found it to be surprisingly elusive on a high percentage of projects. It seems that specifying professionals are no more immune to the possibility of sending mixed messages than I or my SJI associates. I have seen many projects where the specifying professional fell into a very similar communication trap of trying to combine specifications for joists with complex loading in an overly simplified format.

For example, I was reviewing a project the other day that had relatively common roof loading, where all of the joist loads were specified in a total load and live load format, with net uplift in pounds per sq. ft on a key-plan map. It also showed some rather large chord axial loads for many of the joists and girders. Some of the axial loads were in the joist top chords, some in the joist bottom chords, and some were applied to the bottom chord at one end and transferred to the top chord, thru the webs, and thence into the deck diaphragm. The 2006 *International Building Code* (*IBC*) was referenced for load combinations. Needless to say, this combination of project design specifications sparked a host of questions:

1. Which of the three *IBC* 2006 Load Combination sets was I to use, LRFD Basic (1605.2.1), ASD Basic (1605.3.1), or ASD Alternate Basic (1605.3.2)?
2. Were those seismic loads considered to be E or E_m? If E_m, then what were the accompanying E values for inclusion in the appropriate load combinations?

Joseph J. Pote, P.E., is director of engineering research and development for CMC Joist and Deck, Hope, Ark. He is co-chairman of the SJI Research Committee, chairman of the SJI Seismic Sub-Committee, and co-author of the SJI Technical Digest 11, Design of Lateral Load Resisting Frames Using Steel Joists and Joist Girders, *2nd edition.*



These diagrams show a few of the many common load combinations that would have to be assembled from all of the applied load categories (not comprehensive).

3. If this project had axial loads from seismic, then would it not also have similar loads from wind? If so, what were those values, for inclusion in appropriate load combinations? Or could I ignore the load combinations with wind loads, as having already been determined to be non-controlling by the specifying professional?

4. In order to check these seismic loads in their appropriate load combinations, I first needed to know the accompanying loads with magnitudes broken out by category. What were the base load categories and magnitudes?

   a. I was given Live Load, but did not know if it was truly Roof Live, or if it was Roof Snow (the two are managed differently in some load combinations).

   b. I was given Net Uplift, but did not know how much was Wind Load and how much was Dead Load (the two have very different multipliers in most load combinations).

   c. I was given Total Load, but did not know whether I could reliably subtract Live Load from Total Load to get Dead Load, then use Dead Load to add to Net Uplift to get gross uplift Wind Load. Given the number of potentially controlling load combinations for both downward and upward acting loads, this seemed like a risky assumption (plus many structural engineers use a Dead Load range with maximum Dead Load additive to downward-acting loads and minimum Dead Load countering upward-acting loads).

In short, I needed a lot more load and load combination information in order to correctly design the joists and girders. The load data had been overly simplified with too much pre-processing, and I really needed more granular data to work with. To quote a computer-programmer friend of mine, "It is much easier to make an omelet out of eggs than it is to make eggs out of an omelet."

Now, you may be wondering why I needed all that load combination data. Why didn't I simply add the seismic loads to the joist total load condition, and then also add them to the joist net uplift load condition? There are two very good reasons not to do this.

First, many of the lateral loads were quite large, and it would have been very uneconomical to simply lump everything together. Beyond that, I have learned from experience that this seemingly conservative lumping together of loads does not always yield satisfactory results. Load reversals through webs sometimes come into play, as with joist end moments or axial loads migrating from bottom chord to top chord. I find that if I first design the joist based on "conservatively" lumping all of the loads together, then go back and verify the design based on correct building code specified load combinations, it is very common for some of the members to show overstresses under the correct load combinations.

So, what are the available options for specifying joist loads, and what type project might each option apply to? In the instance of a project with simple uniformly distributed design loads, the joist loading requirements may best be communicated by nothing more than a standard joist designation. For a project with more complex loading, the joist loading requirements may best be communicated by providing every load broken down by load category and accompanied by a list of design load combinations. MSC

The author has provided additional material that explains how to present loading information for several of the most common types of loading. This additional information is available in a longer version of this article available in the Modern Steel Construction *archives at* ***www.modernsteel.com/backissues****.*