A new gravity overload steel joist system minimizes sudden collapse potential, providing critical delays in static gravity roof overload situations.

product expert series

NOT JUST ANY JOIST

BY JOE POTE

FOR YEARS, JOISTS HAVE SERVED as an overhead support system. Thanks to a new innovation in joist design, they will also have the opportunity to serve as an early warning system.

The Flex-Joist Gravity Overload System uses a "bend-before-it-breaks" design approach, providing visual warning in the event of extreme gravity overload conditions. While it is not designed to outperform traditional joist systems under lateral or uplift loads such as tornadoes, hurricanes or seismic events, it does offer high ductility and time delay under more common overload scenarios such as rain, snow and floor live loads.

The major goal behind the new joist concept is to provide a tension-controlled design. A tensile yielding limit state offers substantial advantages over the more typical compression buckling limit state.

Strength of slender members in compression is influenced by a variety of variables related to initial offsets, eccentricities in load paths and relative stiffness of adjacent members and connections. Strength of steel members in tension is influenced primarily by cross-sectional area and yield strength. Since members in tension have fewer influencing variables, they have less statistical variance in strength. This results in improved reliability for tension-controlled joists.

Tensile yielding is a much slower limit state than compressive buckling, with more reserve capacity. Tension-controlled joists exhibit substantial ductile behavior with large deflections under sustained (or increasing) plastic load after exceeding the elastic limit. The result is a much slower collapse with large deflections providing visual warning and more time for evacuation.

The plastic reserve capacity of a tension-controlled joist also encourages load sharing between adjacent joists. A joist loaded in excess of the elastic limit continues to support its plastic load capacity, while additional loads are shared with adjacent joists. This load sharing adds system redundancy, thereby reducing system statistical variance and further improving system reliability.

Material Selection and Tension

To encourage tension-controlled joist behavior, the Flex-Joist design uses the joist bottom chord and end web as ductile fuses, with lower design strength than other joist components. The ductile fuse takes advantage of the reduced variance in strength of a tension component to ensure that the strength of the joist is usually limited by tensile yielding, rather than compression buckling.

The benefits are best realized in conditions where the bottom chord and the end web material selection can fully develop the tensile capacity. Sometimes, conditions exist in which bottom chord and end web material selection is not controlled by tension. These include compression under high net uplift loads, axial loads or end moments. In some situations, bottom chord material selection is controlled by strict deflection criteria. In others, bottom chord and end web material selection might be controlled by specified slenderness limits and available bracing or minimum material size criteria.

Relative Strength

The joist top chord and compression webs are designed to be over-strength relative to the primary tension members. The degree of required over-strength is achieved through established relative strength ratio criteria (the member relative strength ratio is the nominal stress ratio of a member divided by the maximum nominal tensile stress ratio of the end web or bottom chord—not less than 0.85).

By setting limits on the relative strength ratios of individual members, control over governing limit states can be exercised. Theoretically, by requiring a relative strength ratio of less than 1.0 on compression members relative to tension members, we can force a ductile tensile yielding limit state. In practice, the relative strength ratios of the compression members must be adjusted far enough below 1.0 to account for some variances in member strengths.

Tension-controlled joist design was studied at Villanova University, in three separate research stages over several years. This research has been used to determine the optimal relative strength ratios to economically achieve a high probability of tension-controlled behavior.

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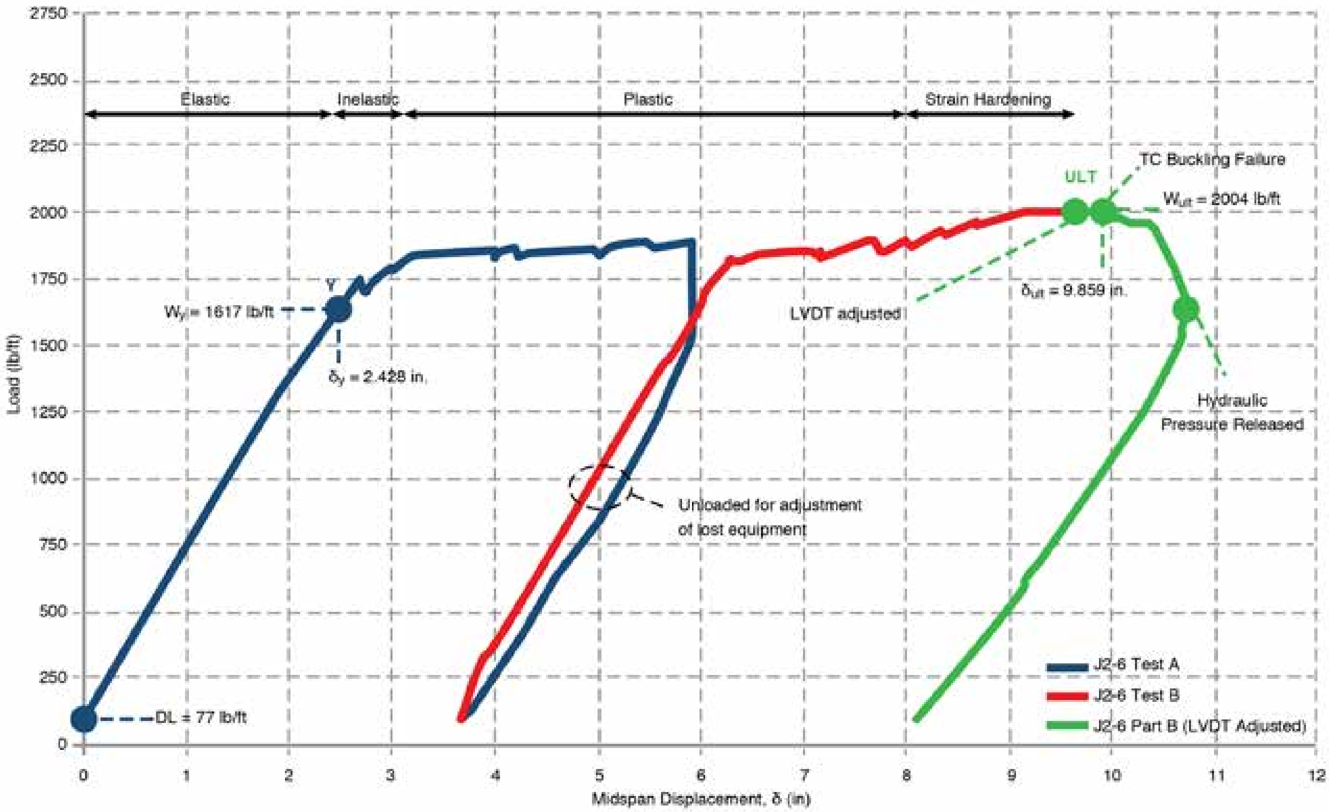

During an overload, the primary limit state established by the Flex-Joist system is characterized by prolonged phases of deflection, moving from the initial elastic phase through to strain hardening, followed by a loss of load-bearing strength, buckling and collapse.

For Flex-Joist's design, the manufacturer, New Millennium Building Systems, uses relative strength ratio restrictions of no more than 0.95 for the top chord and interior tension webs and 0.80 for all compression webs.

Early Warning

A significant additional advantage to the flexible joist concept is electronic monitoring that detects high stress in the bottom chord or end webs. Since the bottom chord and end webs are designed to act as ductile fuses, strain gages placed on these members can reliably monitor roof or floor loading. Electronic monitoring of strain and/or deflection can provide warning when loads approach design level, while the system is still well within the elastic range. This allows for the possibility of load removal or shoring to prevent a collapse. If loading continues to increase toward exceeding system strength, the joist provides a high probability of ductile behavior with large deflections, allowing critical additional time for evacuation prior to collapse.

Electronic monitoring can trigger an alarm signaled locally and/or remotely, to warn of high loads. An alert system can function as a standalone management package or be integrated into an existing building alarm system. On a computer screen, management can see the progression of an overload situation, allowing timely decisions to be made for the most critical building areas.

Specification

The International Code Council Evaluation Service (ICC-ES) is working with New Millennium to develop acceptance criteria for Flex-Joist. The new joist meets or exceeds the American National Standard SJI-K-2010 and/or SJI-LH/DLH-2010. When specifying Flex-Joist, an R-Series joist designation is used. The Flex-Joist designation format is ddRmtl/ll, where:

- dd = nominal joist depth in inches
- m = design method; S for Allowable Stress Design (ASD), F for Load Resistance Factor Design (LRFD)
- tl = total uniform load applied to top chord (plf)
- ll = uniform live load for deflection limitation check (plf)

For example, 24RS200/100 designates an R-Series Flex Joist with:

- 24-inch nominal joist depth
- ASD design method
- 200 plf uniform design load
- 100 plf uniform live load

The new technology is now available, and experts will be on hand to discuss it at New Millennium's booth (1225) at NASCC. MSC