

# Increasing Overhead Capacity

BY PETER MARXHAUSEN, M.S., P.E.  
AND DAVE HENLEY, P.E.

WELCOME TO  
RANGER COUNTRY  
GRAND PRIX MOTORSPORTS

Field-bolted spliced open-web steel joists offer a lightweight and easy-to-install upgrade.

**FOR THE PRACTICING STRUCTURAL ENGINEER**, open-web steel joists can present a challenge when modifying an existing building to accommodate increased loads, floor performance enhancements, and new floor/roof openings. One common reason for modifying an open-web steel joist is the need to install new rooftop equipment that exceeds the original design capacity of the supporting structure. When the existing open-web steel joists are not capable of safely supporting the new loads, it is far preferable to install additional joists to provide the required capacity. However, new full-length joists often cannot be inserted due to the lack of clearance needed to insert the new joist into the existing cavity.

Historically, some structural engineers have turned to their own engineering creativity to modify an open-web steel joist framing system. Modifications have included welding steel plates, angles, channels, and rounds to the joist chords in an effort to increase the gross section modulus of the joist. While that approach has merit, it often does not adequately address the fact that the weak point may be the web members or their attachment to the joist chords. Similarly, welded attachments may not be successful due to difficulties with welding access at the top chord and quality concerns associated with field welding.

Another approach seen in existing buildings is the installation of new steel wide-flange beams adjacent to an existing open-web steel joist. Where this type of modification has been implemented, the end of the steel beam is coped to a depth of 2½ in. and the web is reinforced with steel angles. This installation can present problems similar to the installation of full-length open-web steel joists because a wide-flange beam is often too long and cumbersome to fit into an existing opening. Sometimes the beam may be designed as two pieces with a moment connection near midspan. Although this approach also has merit, the steel beam is often too heavy to match the relative stiffness of the adjacent joists. Such a match is necessary to ensure that the beam will evenly support the proposed loading without overloading and/or causing a premature failure of the existing adjacent open-web steel joists.

Although not widely known, a better approach to strengthening an existing open-web steel joist framing system is to install new field-bolted spliced open-web steel joists supplied by the joist manufacturer. Field-bolted spliced open-web joists are relatively lightweight, they do not require modification of the existing bracing/bridging regime, and may be able to accommodate existing electrical/plumbing/mechanical installations with little modification.

**Opposite page:** Interior of the Grand Prix Motorsports showroom, illustrating the difficulty of doing retrofit construction overhead while allowing the business to remain open.

### Case Study

The two-story Grand Prix Motorsports building is a 34,691-sq.-ft commercial structure in Littleton, Colo. Completed in early 2004, the building has a motorcraft and motorcraft accessories showroom on the first floor and a mezzanine level located on the east side of the building. The west end of the building has a mechanic/repair area on the first floor and a storage warehouse on the second floor. The roof structure was economically designed with open-web steel joists to accommodate the locally prescribed snow load of 30 psf.

The height of the rooftop mechanical screen walls and parapet walls combined with the open nature of the adjacent roof created a condition that could develop significant snow drift loads. In some roof areas the calculated effect of the potential snow drift loads was nearly 100% more than the minimum roof snow load. Unfortunately this was not adequately communicated between the architect and structural engineer of record during the project design phase. As a result, several of the specified roof joists were appreciably underdesigned for the anticipated loading.

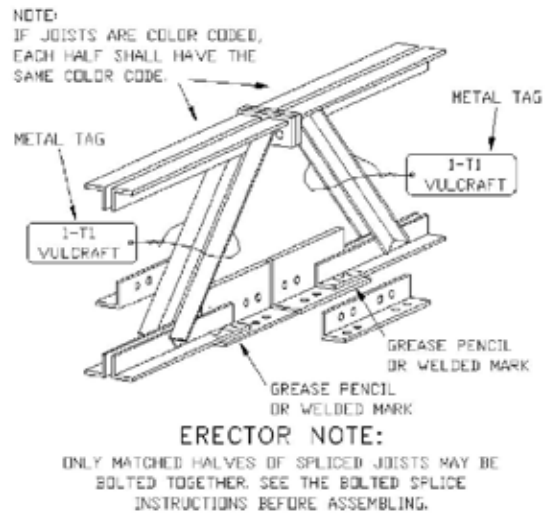
As a precautionary measure, the owner of the facility elected to shovel snow off the roof if it accumulated more than 6 in. Although 6 in. of snow would not overload the joists, the concern was that blowing snow could create drifts at the parapets and screen walls that could overload the roof joists at those areas.

Several options were investigated to strengthen the roof structure including installing wide-flange beams and removing the roof to install new full-length open-web joists. Opening the roof raised concerns with the impact to the existing electrical/mechanical/plumbing installations as well as concerns over the financial impact to the business associated with the disruption. As a result, the roof strengthening repairs were delayed for nearly four years. After investigating several options to strengthen the roof, the original joist manufacturer, Vulcraft, suggested field-bolted spliced open-web steel joists might be an appropriate solution.

Field-bolted spliced open-web steel joists can be manufactured to any standard joist size and are shipped from the manufacturer in two segments. The joists are field-bolted with a moment splice that can be designed to be almost anywhere along the joist. Adjusting the splice location can help accommodate an existing duct or fire suppression line that otherwise would have to be temporarily disconnected or rerouted to install a standard joist.



Field-bolted open web joists were delivered to the job site in two sections with the red oxide primer paint already applied.



MATCHED HALVES OF SPLICED JOISTS



The completed joist installation with angle braces welded into place.



Peter Marxhausen (left) is a forensic structural engineer with Higgins & Associates, Inc. in Morrison, Colo., and an adjunct faculty member with the University of Colorado at Denver Civil Engineering Department. Dave Henley is the Denver district manager for Vulcraft Sales Corporation. He has more than 27 years of experience in the design and construction of open-web steel joists, joist girders, and metal deck.



The 2¼-in. joist seat depth required a ¼-in.-thick shim be welded into place after the joist was erected.

Another benefit of field-bolted joists is that the joist seats can be manufactured with a 2¼-in. height versus the standard 2½-in. height. The reduced seat height provides easier insertion of the joists between the bearing surface and the metal deck. Similarly, the ¼-in. tolerance accommodates some angular movement as the joists are installed. After installation, ¼-in.-thick steel plates are installed beneath the joist seats to provide a tight connection against the metal deck.

In new construction, the top/compression chord of open-web steel joists is laterally braced to resist lateral buckling using screw and/or welded connections to the metal roof deck. When a new flexural member is installed in an existing building, bracing of the top chord is a significant concern. One option is to remove the roofing and screw the metal roof deck to the new joists. Although that is a possibility, the top chord of field-bolted spliced joists can be braced by welding standard steel angle braces to both the new joist and the existing open-web joists.

In the example of Grand Prix Motorsports, existing continuous bridging was installed at the quarter points of the existing open-web joists. To minimize field welding of additional bridging or braces, the new field-bolted steel joists were designed to be braced at the quarter points only. The end result was that the roofing system was

not penetrated and the appearance from below was relatively unchanged.

Repair of the Grand Prix Motorsports facility, including the installation of 20 new field-bolted joists, was completed in approximately two weeks. The repair contractor, The Deer Creek Corporation, indicated that all 20 joists could have been installed in two days; however, the project was sequenced such that only one area at a time would be affected by the construction. All repairs were completed during normal

business hours without interruption to the business operations.

### Design Requirements

Design of field-bolted open-web steel joists is similar to new construction with some minor modifications. The structural engineer of record for the design should provide the following:

1. Existing and new joist layout with joist sizes and layout dimensions.
2. Existing/available bearing widths with clear construction span dimensions.
3. Preferred splice location.
4. Details for the attachment of the new joists to the supporting structure.
5. Specifications regarding the permanent bracing of the top chords.

### Conclusion

There are several methods to strengthen an existing roof structure. Structural engineers are encouraged not to modify open-web steel joists in a manner not accepted by the open-web steel joist manufacturer or the Steel Joist Institute (SJI). As outlined above, one economical way to increase the load capacity of an existing open-web joist roof is to install field-bolted open-web steel joists manufactured by the original joist manufacturer. Although field-bolted spliced joists will strengthen the structure in a localized area, additional calculations are required by the structural engineer of record to ensure the metal roof deck and support girders are adequate to support the proposed loading. **MSC**

### A Little Joist History

The Massillon Open-Web Joist, which was developed in 1923, was the first open-web steel joist system. It consisted of a single continuous web in a Warren-type truss configuration and incorporated two top chord bars and two bottom chord bars. The unobstructed nature of the first open-web joist provided a weight-efficient design that could also easily accommodate electrical/mechanical features within the plane of the roof framing.

The Steel Joist Institute (SJI) was formed five years after the first open-web steel joist was manufactured. In 1929, one year after SJI's founding, the first open-web steel joist load table was developed. That original load table helped unify design standards and eliminate product confusion among architects, engineers, fabricators, and builders. Although modern open-web steel joists consist of either steel angles and rods or just steel angles, the term "bar joist" developed from the early use of continuous round bars is still used as the common nomenclature.

Since SJI's creation, open-web steel joists have been a dominant construction feature in the industry offering weight- and material-efficient designs, long spans, simplified erection, and an unobstructed design that allows for electrical and mechanical conduits. Currently, there are billions of square feet of both roof and floor structures in the United States that have been constructed using open-web steel joists.