WJE

PRIMER

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An Overview of Open Web Steel Joists

The owner or manager of a building that features open web steel joist framing systems for the floors and/or roof may occasionally wonder if they are strong enough to support new or additional loads, and, if not, whether they can be modified to do so. This WJE Primer is intended to provide building owners and managers with a basic understanding of these common structural members, including their history, their unique features, and certain challenges associated with their evaluation and modification.

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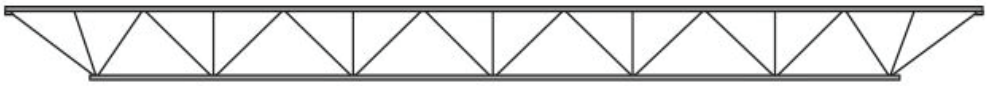

A Brief History

The name open web steel joists may conceal the fact that these "joists" are really "trusses." Trusses made of wood have been utilized throughout the world for centuries, but the use of trusses became far more prevalent in the late 19th and early 20th centuries following improvements in the production of structural metals, such as cast iron and later steel. Today, open web steel joists are one of the most commonly used framing systems for floors and roofs in buildings.

Some of the first steel joists used in the United States in the mid to late 1800s were made of sheet steel webs and flanges riveted together. Use of these members continued into the early 1900s, when quantity production of pressed steel joists made of light gauge steel sheets began to replace the riveted versions. These joists were made by pressing the sheets into the form of channels and welding them back-to-back, giving the appearance of light I-shaped beams. One of the primary objections to these joists was that their solid steel webs provided no practical means of installing conduits and pipes within the depth of the floor and roof members. This and other concerns led to the development of what came to be called *open web steel joists.*

The first open web steel joists in the United States were manufactured in the 1920s. These early steel joists featured top and bottom chords made of round bars, steel angles, or proprietary shapes, with webs commonly formed from single continuous bent bars. As the steel joist industry began to grow, engineers and architects found that the lack of uniform design and fabrication standards among the various manufacturers made it difficult to achieve the most cost-effective structures. Consequently, members of the industry began working to standardize the manufacture of these components. These efforts resulted in the formation of the Steel Joist Institute (SJI), which published its first set of Standard Specifications for Open Web Steel Joists in 1928, followed by the first load tables in 1929. Today, the SJI, a nonprofit organization of active joist manufacturers,

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and other organizations and companies connected to the industry, continues to develop and maintain standards for the design, manufacture, and erection of steel joist construction.

The first SJI Specification permitted the use of rolled shapes or strips of sheet steel, round bars, angles or specially rolled bars riveted or welded together. Modern-day open web steel joists are similar to those produced in the 1920s and 1930s, and all feature top and bottom chords, with diagonal, and sometimes vertical, web members between the chords. Today's steel joists are often fabricated using double angle chords and webs made from angles or round rods. However, the SJI Standard Specification provides performance requirements, and each member company is permitted to use various products and geometries in their joists, thereby providing proprietary designs, so long as the specification is satisfied. This includes the use of both hot- and cold-rolled steel shapes, bars, sheet, and strip. Photographs of a circa 1930 open web steel joist and a modern era K-series open web steel joist are shown in Figures 1 and 2, respectively.

Typical and Atypical Applications in New Buildings

Since they were first published, each SJI Standard Specification has included load tables, which provide allowable uniform loads for various span lengths and joist depths, making it possible for engineers and architects to specify rather than design these types of structural components. Many joist manufacturers provide custom designs of open web steel joists. This is advantageous for applications where the engineer of record specifies specific loadings on the structural drawings as opposed to the standard SJI joist designations. Some manufacturers also allow other variables in the design and fabrication of their open web steel joists, including sloped or curved top chords (rather than the traditional parallel chord joists), variations in the depths of joist bearing seats, sloped bearing seats, greater joist depths, and the ability to incorporate steel joists into the lateral force resisting systems.

New or Additional Loads on Open Web Steel Joists in Existing Buildings

Situations routinely arise where the owners of existing buildings want to make certain alterations, such as installing new and heavier roofing systems, replacing existing rooftop mechanical units with upgraded equipment, or installing rooftop mechanical units where none previously existed. Proposed alterations can also include the installation of heavier flooring materials or high density filing systems, while changes in occupancy may result in increased floor live load requirements or modifications to the roof framing to accommodate snow drift loads that were not necessary when the building was originally designed and constructed. When situations like these arise, the question is often asked: *Can the roof or floor joists in my building support these new loads, and if not, can they be strengthened so that they can?*

Similar to most existing structural components or systems, the load carrying capacities of existing open web steel joists can be estimated; however, the reliability of any such assessment can be affected by a variety of factors. The capacity of existing open web steel joists can be determined with the greatest confidence when the original design, construction, or shop drawings are available. When these documents cannot be obtained, the next best option is to see if joist tags are still in place on the affected joists. A joist tag is a metal label wired to each joist during fabrication that provides information such as the manufacturer's name, job number, mark number, plant location, and date; an example is shown in Figure 3. When joist tags can be retrieved, it is likely that the manufacturer can be identified who

FIGURE 1
Photograph of an open web steel joist circa 1930

FIGURE 2
Photograph of a modern open web steel joist

FIGURE 3
Typical joist tag

Open Web Steel Joists (CONTINUED)

may be able to provide information on the design and fabrication of the joists in question. If the manufacturer is no longer in business, the SJI may be able to provide useful information. Alternatively, when drawings and joist tags are not available, or even if they are, building owners, engineers, and contractors trying to identify existing joists can fill out and submit the *Joist Investigation Form* available on the SJI website, which, we understand, has proven to be an effective and valuable resource.

Finally, if drawings and/or joist tags are not available, and use of the SJI *Joist Investigation Form* has been fruitless, the capacity of steel joists can always be estimated by an experienced structural engineer, using field measurements of the overall geometry and measurements of the joist chords and webs, together with assessments of the various chord-to-web member connections. Evaluations such as this will also require assumptions regarding the yield strength of the steel, which can usually be determined with reasonable accuracy using the SJI Standard Specification that was in use at the time the building was designed and constructed. However, where greater reliability is needed, samples can be retrieved from the joists in question and the material properties determined by tests.

Increasing the Load Carrying Capacity of Existing Open Web Steel Joist Framing Systems

Once the capacities of the existing joists are known within a reasonable degree of engineering certainty, they can be compared to the proposed demands to determine if the new loads can be carried with an adequate factor of safety. When the answer to this question is no, there are

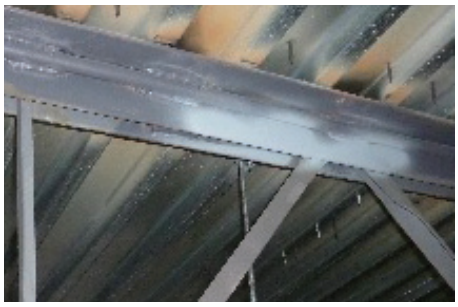

FIGURE 4
Original top chord strengthened with new welded steel rod

FIGURE 5
Original top chord strengthened with a new screw-fastened steel angle

FIGURE 6
Original web members supplemented with new steel angles

FIGURE 7
Original web member strengthened with new steel rod and angles.

Open Web Steel Joists (CONTINUED)

several approaches that can be taken so that the existing framing can be made strong and/or stiff enough to support the proposed load demands. These approaches include:

1. Reinforcing or strengthening the existing joists
2. Adding new joists or steel beams between the existing joists
3. Distributing the loads to several adjacent members.

Approach 1

Reinforcing or strengthening the existing joists can be accomplished in a variety of ways, depending to some degree on the magnitude and extent of the new loads. If the new loads will be applied at discrete locations (e.g. a new roof top mechanical unit), it is possible that only a relatively small number of the joist components will require reinforcement. In this case, the affected chords and webs may be reinforced with new steel rods or angles as shown in Figures 4, 5, 6 and 7. However, if the new loading is applied over a large area (e.g. from a new high density filing system or increased floor live load), all of the joist chords and webs may need to be reinforced in a similar manner.

Alternatively, in some circumstances, it may be possible to strengthen the existing joists by reducing their spans with the installation of a new beam or beams perpendicular to the spans of the joists. In most cases, this would require strengthening at least some of the web members in the vicinity of the new beam or beams. However, this may be a more cost-effective approach than reinforcing all or most of the joists' chords and web members over the entire length of the affected joists.

Approach 2

The addition of new framing, such as steel beams or additional joists between and parallel to the existing joists, is sometimes an option worthy of consideration. If the new loads will be applied at discrete locations, new joists or beams may be designed and installed to support the new loads in their entirety, and relatively independent of the existing loads. However, if the new loads are to be applied over large areas (e.g. from a new high density filing system or increased floor live loads), the new framing will likely have to work in unison with the existing framing to share all the loads. In this case, the stiffness of the new framing will need to approximately match that of the existing members.

The addition of new joists or beams between and parallel to the existing joists may be more challenging than it initially seems. For example, most steel joists are top chord bearing, which means that the top chords extend several inches over the top of the supporting beam, girder, or wall at each end; a very efficient and cost effective bearing detail for new construction. However, in an existing building, it can be very difficult, if not practically impossible, to install a new joist with this same top chord bearing detail that was used for the original joist at each end. One solution is to install the new joists with field-bolted splices. On the other hand, the use of supplemental steel joists or beams supported at the face of the existing supports at one end may eliminate this problem. Other challenges include the possibility that access to the area between existing joists, for installation of new framing members, may be limited by the presence of mechanical ducts, plumbing pipes, and/or electrical conduits. Other difficulties may be encountered because the existing framing will have deflected between supports due to the dead loads already on the structure, and this will need to be considered in the design and installation of the new members.

Approach 3

When the new loads are isolated to a relatively small location of a floor or roof (e.g. when a mechanical unit is to be suspended from the roof or ceiling), it may be possible to distribute the new loads over a number of adjacent joists by the installation of load distribution or spreader beams. This solution is very straight forward when the new loads are small enough that they can be carried by two adjacent joists. However, this approach becomes slightly more complex when the new load must be distributed over several joists so that none are loaded beyond their allowable capacity when the new loads are considered together with the existing dead loads and other code-required design loads. In this case, the spreader beams must be relatively stiff compared to the stiffness of the joists. As an alternative to installation of a stiff beam below the joists, it may be possible to construct a truss perpendicular to and within the depth of the joists to transfer the load appropriately to the existing joists.

Open Web Steel Joists (CONTINUED)

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