Antiquated Structural Systems Series

Part 9b – Open Web Steel Joists

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For this series of articles, "antiquated" has been defined as meaning outmoded or discarded for reasons of age. In reality, however, most of the systems that have been discussed are no longer in use simply because they have been replaced by more innovative or more economical methods of construction.

This article, however, deals with a method of construction that is still very much in use today. Nevertheless, the historic, original construction practices described here may still be encountered in existing structures. Therefore, the primary purpose of this series of articles will be fulfilled, which is to compile and disseminate a resource of information to enable structural engineers to share their knowledge of existing structural systems that may no longer be in use but are capable of being adapted or reanalyzed for safe reuse in the marketplace of today and the future.

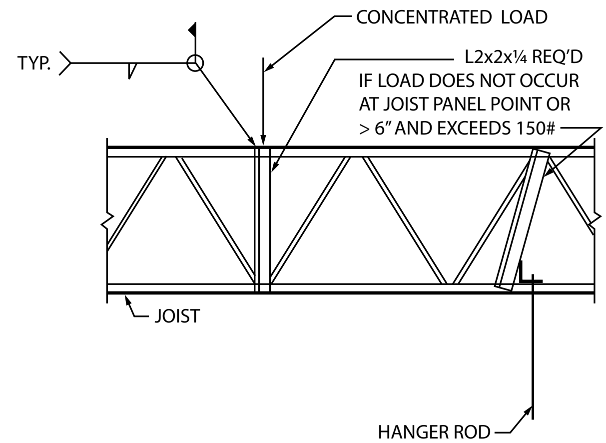

Figure 1: Typical concentrated load on joist detail.

Evaluation and Modification of Existing Joists

The author would first like to thank the Steel Joist Institute (SJI) for providing much of the material that was used in the development of this article. The evaluation and strengthening of existing open web steel joists and Joist Girders is often required as a result of equipment upgrades or new installations and adaptive reuse or change in use of a facility. The SJI provides an excellent resource for the evaluation and modification of existing joists and Joist Girders in *Technical Digest No. #12*.

The first step in the process of evaluating an existing joist is to determine the capacity of the member. Ideally, the best method for doing this is through original construction or shop drawings, which allow the identity of the joist to be established. Similarly, it is also sometimes possible to identify the joist by means of fabrication tags left attached to the joists in the field. However, if tags can be found, more often than not the tag only identifies the shop piece mark number rather than the actual joist designation.

In some instances, it may only be possible to establish the type or series of the joist through the available documentation. In this situation, it is possible to assume conservatively that the capacity of the existing joist is no more than the lightest joist in the corresponding series for the given depth. In addition, if it is not clear whether a J- or H-Series joist is involved, the J-Series joist should always be conservatively assumed because of its lower load-carrying capacity. However, if a definitive distinction is required, and it is possible to secure a material sample in order to obtain results from a standard ASTM tension coupon test, a determination as to whether the joist is 36 ksi (J- Series) or 50 ksi (H-Series) can be made.

If no drawings are available, it is still possible to establish the approximate capacity of the member by field measuring the chord and web member sizes, as well as the overall configuration of the joist. This information can then be used to analyze the structure as a simple truss. Critical assumptions that must be made with this approach include the yield strength of the members and whether the existing panel point welds are capable of developing the full capacity of the connected component members. An alternate method includes filling out the Joist Investigation Form located on the SJI website. SJI has indicated considerable success in identifying the series and designation for many older joists with this resource.

The next step in the evaluation process is to determine all of the existing loads on the joist system. The existing and new loading criteria are then used to establish the shear and moment envelope of the individual joist, for comparison with the allowable shear and moment envelope based on either the historical data provided by SJI or an independent analysis of the member as a simple truss. In the former case, unless the joists were fabricated with a uniform shear and moment capacity over the entire span length (i.e., KCS joists), then it is also necessary to evaluate the location of the maximum imposed moment.

Typically, if the maximum moment is within one foot of the midspan point and the maximum applied moment is less than the joist moment capacity, the joist is capable of safely supporting the imposed loads. However, if the maximum moment is greater than one foot from the midspan point, the capacity of the joist may not be sufficient even if the applied moment is less than the specified capacity. This situation can occur for two reasons. First, the moment capacity envelope of the joist may actually be less in regions of the span that are not within one foot of the midspan point. Second, a shift in the moment envelope from that normally associated with a uniformly loaded simple span (and the prerequisite shear envelope) may result in stress reversals in the web members (i.e., from tension to compression) for which the original member was not designed or manufactured. A similar, although typically more advantageous, condition also can occur with J- or H-Series joists because of variations in the uniform shear capacity of these members.

When the existing joists do not have sufficient capacity to support the new loads, one of three methods can be used to rectify the condition: load redistribution, adding new joists or beams, or reinforcing the existing joists. Load redistribution involves the installation of a sufficiently stiff member perpendicular to the span of the joist as required to distribute the applied load to enough adjacent joists such that no one joist is overstressed as a result of the new loading. Adding new joists or beams typically involves the installation of an additional framing member parallel to the joist span, such that all or most of the new applied load is supported by the new framing. New self-supporting beams can also be installed perpendicular to the joist span, as required to reduce the original span length of the member. Another alternative consists of new independent, self-supporting beam and column frames that avoid the imposition of any new loads on the existing joist framing system. Reinforcing involves the installation of supplemental material to the original joist as required to increase the load-carrying capacity of the member.

The key to the successful use of load redistribution is the installation of a structural member that can adequately and predictably distribute the applied load to enough adjacent joists to justify the safe support of the load. A method of calculating the relative stiffness of a distribution member is available in the reference material noted in the online version of this article. In general, if the spacing of the joists is less than approximately 78% of the calculated relative stiffness of the distribution member and the joists, and the length of the distribution member is less than the inverse of the calculated relative stiffness, then the distribution member may be considered as rigid enough to calculate the static load reactions to the affected joists.

For load redistribution solutions, it is the author's preference to use trussed distribution members, rather than individual beams, to ensure adequate transfer of the applied load. Trussed means continuous members located perpendicular to both the bottom and top chords of the existing joists in conjunction with diagonal web members connected to the continuous members at the intersection of the joist chords. The resulting configuration looks like a truss and provides greater stiffness than an individual beam connected to either the bottom or top joist chords alone. The author also recommends that no more than five joists be engaged by any one redistribution member. In addition, the use of pipes for the continuous redistribution truss chord members can be advantageous, as this type of section fits neatly through the V-shaped panel point openings created at the intersection of the existing chords and web members. However, load redistribution solutions may be difficult to install, depending on accessibility and the presence of existing MEP systems, ceilings or other appurtenances.

As indicated above, adding new joists or beams to an existing system can also be used to accommodate new loads on an existing joist structure. When new members are added parallel to the existing joists, the new framing can be used either to reduce the tributary area of the existing joists or to provide direct support of the new loads such that there is no impact on the existing joists. Methods used to install new parallel framing often involve manufacturing, shipping and erecting the new members using field splices. However, it is possible to install new full-length manufactured joists by means of loose end bearing assemblies. In this scenario, the joists are first erected on a diagonal to allow the top chord to be lifted above the bearing elevation. The joist is then rotated into an orthogonal position, with the lower portion of the bearing assembly then dropped and welded into place. Typically, in this situation, a shallower bearing seat is also provided for ease of installation and then shimmed once the new joist is in its proper position.

When new beams or other similar members are added perpendicular to the joist span, the new framing serves to reduce the span of the existing members, thereby increasing the load-carrying capacity of the joists. However, it is still necessary to analyze the existing joists to ensure that no load reversals have occurred in tension-only web members, and that the actual applied moment falls within the remaining existing moment capacity envelope of the joist. As with load redistribution solutions, both of the above new framing approaches may be difficult to install.

New framing that involves the installation of independent, stand-alone beam and column frames is intended to provide direct support of the new loads such that there is no impact on the existing joist framing. This type of new

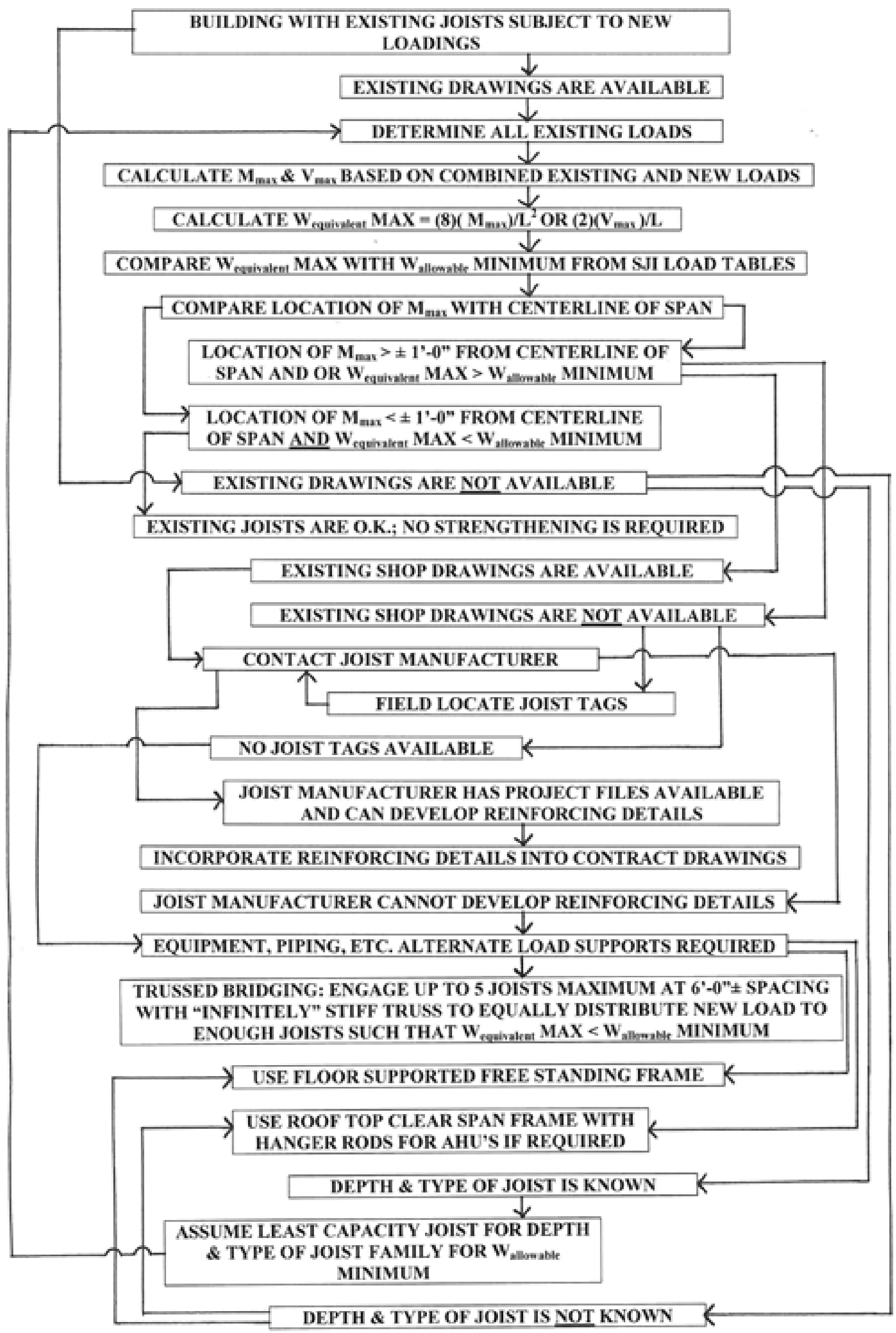

Figure 2.

framing can involve beams located either beneath or above the impacted existing framing and supported by new columns and foundations, or beams that frame between existing columns. This type of solution can also involve new beam frames supported from posts located directly above existing beams or columns. The above solutions are typically more adaptable to the presence of existing MEP systems, ceilings or other appurtenances.

Procedures for reinforcing joists are expertly described in *SJI Technical Digest No. #12* and involve two basic approaches: 1) ignore the strength of the existing member and simply design the new reinforcement to carry all of the applied load, or 2) make use of the strength of the existing member when designing the reinforcing. Both of the recommended approaches typically involve significantly more labor costs than material costs because of the expense associated with field welding.

The author prefers to avoid the use of field reinforcement for the following reasons. A manufactured open web steel joist is basically a pre-engineered product; however, when an engineer involved with the modification of an existing joist specifies new field installed reinforcement, that same engineer assumes the responsibility for the overall adequacy of the joist. This liability extends to not only the reinforcing modifications but also, inherently, to any pre-existing, unknown conditions or deficiencies in the joist. In addition, field welding associated with the installation of reinforcement also poses concerns for the design engineer. Problems associated with field welding are discussed in *Technical Digest No. #12* and include temporary localized loss of the material strength of the existing steel due to heat generated by the weld, induced eccentricities, inadequate load path mechanisms, and lack of access, particularly at the top chord.

The only exceptions that the author makes include the installation of supplemental web members as needed to transfer concentrated loads greater than 150 pounds on chords that are located greater than 6 inches from a panel point to the closest adjacent panel point (*Figure 1, page 18*), and reinforcement designed by the original manufacturer's engineer. The first exception is the author's rule of thumb and is not formally endorsed by SJI, because it is not applicable in all cases; for example, it may be fine for a 30K12, but not for a 10K1.

The analysis of existing open web steel joists can be a challenging undertaking and often involves a considerable amount of detective work. Unfortunately, there is typically little or no documentation available concerning the capacity of a specific existing joist under investigation. However, it is hoped that the reference information provided in the online version of this article will assist in increasing the likelihood that the capacity of a joist can be determined using the historical data that is available from SJI.

Typically, the investigation of an existing joist results in the need to modify the structural system to provide for the support of new imposed loads. At this juncture, the engineer must then determine if he or she is more comfortable with assuming the responsibility and liability for modifying a pre-engineered product or employing a possibly less risky option, such as load redistribution or adding new joist or beam framing. To assist structural engineers with the evaluation and modification process, the author has included a copy of a flowchart (*Figure 2, page 19*) that was developed as result of numerous projects that involved existing joists.▪

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