Specifying Steel Joists, Joist Girders and the IBC 2006

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INTRODUCTION

The International Building Code (IBC) recognizes the Steel Joist Institute (SJI) Standard Specifications for the design, manufacture and use of open web steel joists and Joist Girders. While the reference to the SJI Specifications limits the amount of wording in the IBC that is devoted to steel joists, there are a number of important passages in the IBC that relate to steel joists, both defining the responsibilities and process for utilizing steel joists and for loads and conditions that affect the selection, design and use of steel joists. This paper will examine the pertinent links and interaction between the IBC and the SJI Specifications, and how both documents work together to define the proper manner to specify steel joists and Joist Girders.

STEEL JOISTS 2206.1 GENERAL

This IBC section lists the three SJI Standard Specifications currently recognized by the IBC: the K-Series Specification and Load Tables, the LH/DLH-Series Specification and Load Tables, and the Joist Girder Specification [SJI, 2005]. The Steel Joist Institute is a nonprofit organization comprised of active joist manufacturers and other individuals and entities that sets the standards and develops regulations for the steel joist industry. The SJI has a staff that includes a Managing Director, Technical Director, and Consulting Engineer and is governed by a Board of Directors, with representation from each member company. The research, promotion, and standardization of steel joist products by the SJI is undertaken by various committees comprised of both SJI staff and member company professionals. Membership in the SJI is obtained by a design submittal, full-scale load testing, and a plant inspection. While the SJI is responsible for maintaining each of the three referenced specifications, a recognized accreditation process is required for inclusion as an IBC Referenced Standard. The SJI achieves this through the American National Standards Institute (ANSI). In the future, the SJI hopes to also include its Code of Standard Practice as a referenced standard, as well as the newly developed CJ-Series Specification and Code of Standard Practice for Composite Steel Joists.

Section 2206.1 also provides a cross reference to IBC section 2205.2 Seismic requirements for steel structures. Section 2205.2 will be discussed later in this paper, in conjunction with Earthquake Loads.

Prior to the 2006 edition of the IBC, section 2206 was limited to this one section. However, four new sections were added for 2006 – the result of a collaborative effort between the SJI and the National Council of Structural Engineers Associations (NCSEA).

It began with a proposal from the NCSEA through its Code Advisory Committee (CAC) during the last Code Development Cycle. The intent was to close a perceived "responsibility gap" between the joist manufacturer and the Specifying Professional (also referred to as the Engineer of Record or the Registered Design Professional). Specifically, there was a concern that critical tasks in the joist engineering process were being performed by technicians or detailers, without supervision of the Joist Manufacturer's Registered Design Professional (JMRDP), and that these items then appeared only on the joist placement plans. SJI submitted an alternate code change proposal for consideration. The key difference between the two proposals was that the NCSEA proposal required the JMRDP to sign and seal joist placement plans, which are commonly (and incorrectly) referred to as "shop drawings".

The NCSEA and SJI felt the necessity to get together to attempt to resolve their concerns and attain consensus language that both could accept prior to the formal code hearings. As a result of many meetings, exchanged emails, long discussions, and polling of memberships, an alternative proposal (floor modification) was achieved, for introduction at the hearings. The four new proposed sections to be added to the code were subsequently ratified and will now be discussed individually.

STEEL JOISTS 2206.2 DESIGN

The language of this section identifies the requirements for steel joist and Joist Girder design that need to be shown on the structural drawings by the Specifying Professional. In short, it defines the responsibilities of the Specifying Professional, which begins with establishing the joist and Joist Girder designations in accordance with the SJI Standard Specifications, and also includes the requirements for joist layout, end supports, anchorage and bearing connection design for uplift and lateral loads, and bridging termination connections. The structural drawings shall include the requirements for special loads and conditions such as:

- Concentrated loads
- Non-uniform loads, such as snow drifts
- Net uplift loads (the load combination result of the wind and dead load)
- Axial loads and end moments
- Connection forces
- Profiles for joist configurations other than those in the SJI Specifications
- Oversized web openings
- Extended ends
- Deflection criteria more restrictive than the SJI Specifications

It should be noted that the industry standard is to design joist extended ends for the same uniform loads as the joist main span, unless specified otherwise. Several options are available to accommodate special or non-uniform extended end loads. The SJI offers two sets of standard extended ends – Type S and Type R. The SJI Load Tables for these extended ends provide both uniform load capacities and physical cross-sectional properties (elastic section modulus and moment of inertia) to create an "envelope" of capacity for non-uniform loads.

For short spans, less than 8 feet, the Specifying Professional should select a joist substitute from the SJI K-Series Joist Substitute Tables. These tables provide the total load and live load capacities in the same manner as the K-Series Joist Load Tables.

STEEL JOISTS 2206.3 CALCULATIONS

This section states that the JMRDP shall incorporate the information denoted in section 2206.2. The calculation package is the JMRDP's interpretation of such information and is subject to signing and sealing by the JMRDP, if requested. This is generally accomplished by signing and sealing a "cover letter" rather than each calculation page that may be involved. The special details noted in this section, by inclusion in the calculation package, are covered by the signed and sealed cover letter. Therefore, use of these details, such as on the joist placement plans, is permitted without the need for further sealing. Examples of the types of special details to be included in the joist calculation package include flush-framed or framed end connections (rather than underslung, simply-supported), special or specific bridging row locations, field splice details, and joist header designs.

STEEL JOISTS 2206.4 STEEL JOIST DRAWINGS

The joist manufacturer does not create "shop drawings" for the manufacture of steel joists and Joist Girders. This is accomplished through computer-generated "cut sheets" and CNC input, as much of the manufacturing is done through automation. What is created, however, are joist placement plans for field installation. This section requires that the joist placement plans include, as a minimum:

- The applicable loads from section 2206.2, which may be simply a part of the joist designation, or be displayed in note format to supplement the joist designations, or be shown on the framing plan, or may be displayed in a load diagram or schedule.
- Profiles for special joist shapes not adequately described by the joist designation.
- Details for connection requirements for joists and Joist Girder supports, bridging attachments and field splices.
- Deflection criteria for non-standard SJI joists.
- Joist header installation details.
- The sizes and locations for all joist bridging members.

Most joist bridging is prescriptive. That is, the number of rows, and the size of bridging members to be used is established simply by reading the SJI charts and tables. In this case, illustrating the bridging requirements on the joist placement plans is not a design function. If the bridging deviates from what would be dictated by the SJI charts and tables, then it should also be reflected in the joist calculations, as noted in section 2206.3 above. The details for the connections for bridging termination to other parts of the structure is the responsibility of the Specifying Professional as noted in section 2206.2 above.

The joist placement plans are not required to carry the seal or signature of the JMRDP, as it would be inappropriate for one engineer to adopt another engineer's design work as his own.

STEEL JOISTS 2206.5 CERTIFICATION

As assurances for other parties, the steel joist manufacturer may be asked to submit a certificate of compliance. This section coincides with section 1704.2.2 Fabricator approval, and the certificate of compliance shall state that the work was performed in accordance with the approved construction documents and with the SJI Specifications.

CONSTRUCTION DOCUMENTS 106.3.4.2 DEFERRED SUBMITTAL

Since the SJI Standard Specifications are accepted in the IBC, the products governed under these specifications do not need to receive approval from a building official on a project by project basis. The calculations submittals for joists, when requested, fall under "deferred submittal" in accordance with section 106.3.4.2. The Specifying Professional must review and accept the submittal documents to be in general conformance with the design of the building. Neither the design professional nor the building official needs to verify design methodology of the joists since they have been previously accepted into the building code. However, the building official's approval is required prior to the erection of the joist products.

FIRE RESISTANCE RATINGS AND FIRE TESTS 703.3

IBC allows the use of fire-resistance designs documented in approved sources, and numerous fire-rated assemblies listed by Underwriters Laboratory (UL) include steel joists. Where a UL rated assembly is being utilized, it should be shown clearly on the structural drawings as certain assemblies require limitations on the steel joists, such as joist spacing limits, minimum joist or bridging sizes, minimum joist component areas, or allowable stress limitations.

PRESCRIPTIVE FIRE RESISTANCE 720

As an alternate to a UL rated fire assembly, Table 720.1 provides prescriptive options for protection of steel joist floor and roof systems.

AUTOMATIC SPRINKLER SYSTEMS 903.3 INSTALLATION REQUIREMENTS

IBC references NFPA 13 for the installation of sprinkler systems. For ESFR sprinkler systems, installed above the joist bottom chord within the depth of the joist, clearance requirements must be maintained between the sprinkler elements and joist elements, including bridging. The joist manufacturer will normally take care of the coordination of the ESFR locations, but should be made aware of the presence of an ESFR system by a note on the structural drawings.

REQUIREMENTS FOR ROOF COVERINGS 1507

This section imposes requirements for the minimum slope of roofs supported by steel joists. The typical roof covering types used in conjunction with steel joist construction would typically fall under sections 1507.4 Metal roof panels (i.e. standing seam roofs);

1507.10 Built-up roofs; 1507.11 Modified bitumen roofing; 1507.12 Thermoset single-ply roofing; and 1507.13 Thermoplastic single-ply roofing. For each of these types, IBC requires a minimum roof slope of one-fourth unit vertical in 12 units horizontal (2 percent, or 1/4:12), with the exception of coal-tar built-up roofs. This can be accomplished by providing either a slope along the length of the joist or perpendicular to the joist span. The Specifying Professional should establish the desired joist bearing elevations to achieve the minimum required slope.

While the IBC requires a minimum roof slope of 1/4 to 12 for most roof covering types, the SJI Specifications have traditionally indicated that the standard slope for pitched joists is 1/8 to 12. This should not be interpreted to supersede the IBC requirements, and this discrepancy will be removed in the next edition of the SJI Specifications to be in conformance with the IBC.

When specifying steel joists with roof slopes well in excess of the minimum required slope, consideration should be given to the following three items. First, adequate bearing seat depth should be specified. The SJI and individual manufacturer publications provide charts suggesting increased seat depth for various slopes. Second, when joists will be installed along a slope, the load table load shall be taken as perpendicular to the joist span, along the sloped length. Third, for slopes perpendicular to the joist span - tilted joists - the vertical load is resolved into components in-plane (to be carried by the joist) and out-of-plane (to be considered by the Specifying Professional, normally as part of the metal deck diaphragm design).

GENERAL DESIGN REQUIREMENTS 1604.3.1 DEFLECTION

The discussion of deflection as it pertains to steel joists should include a discussion of camber. Although the IBC does not require camber, the Steel Joist Institute does (see Tables 4.6-1, 103.6-1, and 1003.6-1for the K-Series, LH/DLH-Series and Joist Girder camber, respectively). These tables for approximate camber are based on a radius of 3600 feet and have historically proven to work well in practical use. The Specifying Professional should be mindful of the standard camber for joists when this camber could affect adjacent framing elevations, including adjacent joists of different lengths, and specify a “special or reduced” camber when necessary.

The SJI Specifications for K-Series, LH/DLH-Series and Joist Girders state that the deflection due to live load shall not exceed the following:

Floors: 1/360 of span
Roofs: 1/360 of span where a plaster ceiling is attached or suspended
1/240 of span for all other cases

To aid the Specifying Professional in determining the appropriate designation, the K-Series and LH/DLH-Series Load Tables include a live load value which is the nominal live load per linear foot of joist which will produce an approximate deflection of 1/360 of the span. Live loads which will produce a deflection of 1/240 of the span may be obtained by multiplying the figures in shown in red by 1.5.

The IBC would appear to recommend more stringent deflection criteria when referencing Table 1604.3 Deflection Limits. This table includes a dead load plus live load deflection limit in addition to the live load deflection limit, whereas the SJI Specifications have no requirements for a “total load” deflection limit. However, footnote (g) states “For steel structural members, dead load shall be taken as zero”.

Therefore, for steel joists, the more stringent live load deflection limit governs and the deflection limits required by the SJI Specifications meet the IBC limits, and in some cases are more stringent.

Deflection limits and camber must both be considered when specifying steel joists. It is recommended that the SJI Specifications be followed unless project specific requirements warrant more stringent deflection or camber criteria. Serviceability should also be a consideration on every project and total load deflection criteria may seem like a benign way to enhance a projects' serviceability by making the joists stiffer. However, this additional stiffness will increase the amount of camber that remains in the joist after installation and may make deck transition more difficult. In addition, it will increase the amount of camber that remains in the joist after final construction and could alter the roof's slope and drainage.

LIVE LOADS 1607

Live loads are important considerations for both strength and serviceability of a structure. It is necessary to convey information regarding live loads and deflection requirements due to live loads on the structural drawings. The K-Series and LH/DLH-Series Load Tables provide the nominal live loads per linear foot of joist which will produce a deflection of 1/360 of the span. This enables the Specifying Professional the ability to select a joist designation that not only meets the total load strength requirements of the project, but also the live load serviceability requirements.

When it is necessary for the joist manufacturer to design for loads in addition to the uniform loads as required by the selected designation, the loads must be defined on the structural drawings as dead loads, live loads, wind loads, etc. to enable the joist manufacturer to properly design the joist.

Live load reductions should be considered when determining the appropriate joist or Joist Girder designation. The designation shown on the structural drawings should be the designation selected after the live load reductions have been taken into account. It is not appropriate to select a designation before a live load reduction has been used and state that a live load reduction may be taken where allowed by the code.

SNOW LOADS 1608

Snow loads can affect the design and designation selection of joists in ways that may not be immediately apparent to some Specifying Professionals. The IBC references chapter 7 in ASCE/SEI 7-05 [ASCE, 2005] which discusses considerations for unbalanced snow loads for Hip and Gable Roofs, Curved Roofs, Dome Roofs, Multiple Folded Plate Roofs, Sawtooth Roofs and Barrel Roofs. It may also be necessary to consider the cases of partial loading, drifts on lower roofs, roof projections, sliding snow, rain on snow surcharge.

In many of these cases, the Specifying Professional will be able to select a standard joist designation from the SJI Load Tables. In other cases, it will be necessary for the loads to be presented in a table or diagram on the structural drawings in order for the joist manufacturer to properly design the joist. Particular attention should be paid to snow drifts as they can create extreme localized load-carrying requirements. It is not appropriate to determine an "equivalent" uniform load for a joist based on a snow drift

load at one end and select a larger joist designation. The local bending effects of the snow drift on the end panel of the joist must be accounted for in the design of the joist.

WIND LOADS 1609

IBC references ASCE/SEI –7-05 for the determination of wind loads. The Specifying Professional shall consider the effects of both upward and downward wind forces on the roof. The joist total load should represent the maximum result of the load combinations of sections 1604, which may include a downward wind force in the controlling case. Note that for Allowable Strength Design, the load combinations involving downward wind allow a factor of 0.75 for load cases involving live load and wind. Hence, it may be possible to categorically establish that the downward wind will not be part of the controlling load case depending on the ratio of downward wind to live load. However, note that for Load and Resistance Factor Design, the downward wind can not be categorically discounted.

In many cases, the ASCE simplified method is applicable to steel joist structures. Care should be taken not to confuse the ASCE net pressure (the resultant of internal and external pressures) with the SJI description of providing the net uplift (the load combination of dead and wind load).

The Specifying Professional shall establish the dimensions of the edge strips and zones (dimension "a"), although this can be displayed as a key plan for application by the joist manufacturer, rather than as a load diagram or schedule.

Steel joists and Joist Girders can be utilized as part of the structure's lateral load resisting system, but the frame analysis and/or diaphragm design are the responsibility of the Specifying Professional.

RAIN LOADS 1611.1 DESIGN RAIN LOADS

The Specifying Professional should not overlook the design rain load of this section or presume that it will not exceed the minimum roof live load of section 1607. For roofs that do not have free, unrestricted drainage, IBC establishes the design rain load as $R=5.2(d_s+d_h)$, where d_s is the depth of water between the undeflected roof elevation with a blocked primary drainage system and the inlet elevation of the secondary drainage system, and d_h is the additional depth of water above the inlet based upon the flow rate of the secondary drainage (i.e., the hydraulic head). An elevation difference between primary and secondary drains combined with a hydraulic head of two inches, which is not uncommon, results in a peak rain load of 26 psf, which in the areas adjacent to the secondary drains would clearly exceed even an unreduced live load of 20 psf. Even if the slope of the joist is such that the rain load forms a triangle that does not span the entire joist length, it could still create a controlling load case for certain elements of the joist near the low bearing end. The SJI Technical Digest No. 3, *Structural Design of Steel Joist Roofs to Resist Ponding Loads* [SJI, 2007] provides examples for the determination of the design flow, hydraulic head, and rain loads.

RAIN LOADS 1611.2 PONDING INSTABILITY

This section only requires a check of stiffness to preclude progressive deflection (ponding) if the roof slope is less than 1/4 inch per foot and, as established from section

1507, almost all joist supported roofs will have at least a 1/4 to 12 slope. However, in the case of a significant rain or impounded water load along the full length of a steel joist (perpendicular to the roof slope), the additional accumulation of water due to the deflected shape becomes significant and merits attention from the Specifying Professional. The technical digest provides a method for considering the deflected shape while accounting for the beneficial effect of the joist camber.

EARTHQUAKE LOADS 1613

Like the wind loads of section 1609, seismic load resisting systems can utilize steel joists and Joist Girders, but the Specifying Professional is responsible for the frame design and/or the diaphragm design. As shown in section 2205.2 Seismic requirements for steel structures, Seismic Design Categories D, E, and F require the design and detailing requirements of AISC 341 [AISC, 2005]. For Categories A, B, and C, the detailing requirements in AISC 341 can be avoided by limiting the *R* factor, and this is recommended. The structural drawings should clearly indicate if the structure is in Category D, E, or F, or if an *R* factor is other than that designated for "structural steel systems not specifically detailed for seismic resistance". The SJI Technical Digest No. 11, *Design of Lateral Load Resisting Frames Using Steel Joists and Joist Girders*, [SJI, 2007] provides further guidance on ordinary moment frames using steel joists and Joist Girders.

Where seismic forces include an overstrength factor, the value of both E and E_m should be provided so that the usual load combinations can be used with E and the special load combinations of section 1605.4 can be used with E_m.

LOAD COMBINATIONS 1604

The IBC lists load combinations that must be used in the design of the structure. The Specifying Professional is responsible for examining all of these load combinations before determining the joist and Joist Girder designations, not just live load and dead load. In many cases, the load combinations which include positive wind loads will govern the designation (see section 1609 Wind Loads). It is important to keep in mind the information that must be conveyed to the joist manufacturer for them to properly design the joists. The joist designation only provides the total uniform load and a live load that will produce a deflection of 1/360 of the span. When only a joist designation is provided, the joist manufacturer will not be able to check any load combinations that include wind or seismic loads because the dead load and live load components would not be known, only the total load. When additional load cases, including wind or seismic loads, must be analyzed by the joist manufacturer, the Specifying Professional should list the dead load and live load in addition to the wind and/or seismic loads on the structural drawings.

The ASD load combination of 0.6D + W must be examined by the Specifying Professional. The industry standard for joist and Joist Girder design is for the Specifying Professional to provide the net uplift, which is the result of this load combination. The Specifying Professional should use the minimum sustained dead load rather than the maximum design dead load for this combination, if there is a difference. For many projects, the joist and Joist Girder designations and the net uplift requirement is all that is necessary for the design of the joists and Joist Girders.

When using Load and Resistance Factor Design (LRFD), the Specifying Professional will need to examine the load combinations in much the same way to determine what information will be required for the joist manufacturer to properly design the joists and Joist Girders. The SJI Specifications contain load tables and weight tables to allow a specifier to select standard SJI designations using LRFD. When the designation and net uplift (factored) are the only design requirements that must be considered by the joist manufacturer, it is not necessary to provide the components used to determine the designation or net uplift. When selecting a Joist Girder, the "K" at the end of the designation has been replaced with an "F" to represent a factored load. The joist designations have not changed. If there are any loads or load combinations that must be considered by the joist manufacturer other than the designation and net uplift, the components for the load combinations must be provided as un-factored loads, to enable the joist manufacturer to use them in the appropriate load cases.

SPECIAL INSPECTIONS 1704.2.2 FABRICATOR APPROVAL

Special in shop inspections are not required for the joist products when the joist manufacturer is properly approved to perform this work. This approval is based on the written shop and quality procedures followed by the manufacturer in the everyday processes that they use. Manufacturers that demonstrate that their quality procedures and practices meet or exceed the standards are not subject to in-house inspections common with some other less standardized manufactured products.

SPECIAL INSPECTIONS 1704.3.1 WELDING

The IBC states that welding inspection shall be in compliance with AWS D1.1 [AWS, 2006]. In addition, Table 1704.3 lists verification and inspection requirements. These requirements are for verification and inspection of field welds, or anchorage, as they pertain to steel joists. The welds used in the manufacture of steel joists are governed by the SJI specifications, not AWS D1.1. Compliance with AWS criteria will satisfy the SJI welding requirements and, in many cases, the SJI criteria are in compliance with a particular AWS provision. However, there are some differences which are detailed in SJI Technical Digest No. 8, *Welding of Open-web Steel Joists and Joist Girders* [SJI, 2008]. It is not appropriate to specify AWS D1.1 requirements for the welds used in the manufacture of the joists.

CONCLUSION

Steel joists and joist girders provide an economical framing system for many types of structures. Successful and proper use of steel joist products requires a combined understanding of both the IBC and the Steel Joist Institute Standard Specifications. The new 2006 IBC language and sections 2206.2 thru 2206.5 have defined the responsibilities of the Specifying Professional and the joist manufacturer. This paper has provided a discussion, by reviewing the pertinent sections of the IBC, of these responsibilities as well as other design considerations and has provided guidance for the application of these sections when specifying steel joists and Joist Girders.

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