

# COMPUTERS & STRUCTURES, INC.

STRUCTURAL AND EARTHQUAKE ENGINEERING SOFTWARE

**ETABS**® 2016  
Integrated Building Design Software

## Steel Joist Design Manual

SJI-K-2010, SJI-LH/DLH-2010





**Steel Joist  
Design Manual  
SJI-K-2010, SJI-LH/DLH-2010  
For ETABS® 2016**

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# Chapter 1

## Introduction

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The design/check of steel joist is seamlessly integrated within the program. Initiation of the design process, along with control of various design parameters, is accomplished using the Design menu. Automated design at the object level is available for the Steel Joist 2010 design code, as long as the structures have first been modeled and analyzed by the program. Model and analysis data, such as material properties and member forces, are recovered directly from the model database, and are used in the design process in accordance with the user defined or default design settings. As with all design applications, the user should carefully review all of the user options and default settings to ensure that the design process is consistent with the user's expectations.

Chapter 2 addresses prerequisites related to modeling and analysis for a successful design in accordance with "SJI-K-2010 and SJI-LH/DLH-2010." Chapter 3 provides detailed descriptions of the specific requirements as implemented in "SJI-K-2010 and SJI-LH/DLH-2010."

### 1.1 Load Combinations

The design is based on a set of user-specified loading combinations. However, the program provides default load combinations for each supported design code. If the default load combinations are acceptable, no definition of additional load combinations is required.

## 1.2 Stress Check

Steel joist design/check consists of calculating the flexural, axial, and shear forces or stresses and deflection due to live load at several locations along the length of a member, and then comparing those calculated values with acceptable limits. That comparison produces a demand/capacity ratio, which typically should not exceed a value of one if code requirements are to be satisfied. The program follows the same review procedures whether it is checking a user-specified shape or a shape selected by the program from a predefined list.

Program output can be presented graphically on the model, in tables for both input and output data, or in calculation sheets prepared for each member. For each presentation method, the output is in a format that allows the engineer to quickly study the stress conditions that exist in the structure, and in the event the member is not adequate, aid the engineer in taking appropriate remedial measures, including altering the design member without re-running the entire analysis.

The implementation covers loading and load combinations from "ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures" (ASCE 2010). Both LRFD (Load and Resistance Factor Design) and ASD (Allowable Strength Design) provisions are included in this implementation under the same "SJI-2010" code name. The LRFD and ASD are available as two options in the program's preferences feature. In both cases, the strengths are calculated in the nominal levels. The phi (LRFD) and Omega (ADS) factors are applied during calculation of demand/capacity ratios only. The design codes supported under "SJI-2010" are written in kip-inch units. All the associated equations and requirements have been implemented in the program in kip-in units. The program has been enabled with unit conversion capability. This allows the users to enjoy the flexibility of choosing any set of consistent units during creating and editing models, exporting and importing the model components, and reviewing the design results.



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## Chapter 2

# Modeling, Analysis and Design Prerequisites

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This chapter provides an overview of the basic assumptions, design preconditions, and some of the design parameters that affect the design of steel frames.

For referring to pertinent sections of the corresponding code, a unique prefix is assigned for each code.

- Reference to the SJI-K-2010 and SJI-LH/DLH-2010 code is identified with the prefix "**SJI**."
- Reference to the ASCE 7-2010 code is identified with the prefix "**ASCE**."

### 2.1 Check and Design Capability

The program has the ability to check the adequacy of a section (shape) in accordance with the requirements of the selected design code. Also the program can automatically choose (i.e., design) the optimal (i.e., least weight) sections from a predefined list that satisfies the design requirements.

To check adequacy of a section, the program checks the demand/capacity ("D/C") ratios at a predefined number of stations for each design load combination. It calculates the envelope of the D/C ratios. It also checks the other requirements on a pass or fail basis. If the capacity ratio remains less than or equal to the D/C ratio limit, which is a number close to 1.0, and if the section

passes all of the special requirements, the section is considered to be adequate; otherwise the section is considered to have failed.

To choose (design) the optional section from a predefined list, the program first orders the list of sections in increasing order of weight per unit length. Then it starts checking each section from the ordered list, starting with the one with the least weight. The procedure for checking each section in this list for adequacy is exactly the same as described in the preceding paragraph. The program will evaluate each section in the list until it finds the least weight section that passes the code checks. If no section in the list is acceptable, the program will use the heaviest section but flag it as being overstressed.

To check adequacy of an individual section, the user must assign the section using the **Assign** menu. In that case, both the analysis and design section will be changed.

To choose the optimal section, the user must first define a list of steel sections, the *Auto Select* sections list. The user must next assign this list, in the same manner as any other section assignment, to the frame members to be optimized. The program will use the median section by weight when doing the initial analysis. Refer to the program Help for more information about Auto Select sections lists.

## 2.2 Analysis Sections vs. Design Sections

Analysis sections are those section properties used to analyze the model when an analysis is run. The design section is whatever section is used in the steel frame design. It is possible for the last used analysis section and the current design section to be different. For example, an analysis may be run using a 12K5joist, and then in the design, it may be found that a14K1joist works. In that case, the last used analysis section is the 12K5 and the current design section is the 14K1. Before the design process is complete, verify that the last used analysis section and the current design section are the same. Refer to the program Help for more information about completing this task.

The program keeps track of the analysis section and the design section separately. Note the following about analysis and design sections:

- Assigning a frame section property assigns the section as both the analysis section and the design section.
- Running an analysis always sets the analysis section to be the same as the current design section.
- Assigning an Auto Select section list to a frame object initially sets the analysis and design section to be the section in the list with the median weight.
- Unlocking a model deletes the design results, but it does not delete or change the design section.
- Altering the Design Combinations in any way deletes the design results, but does not delete or change the design section.
- Altering any of the steel frame design preferences deletes the design results, but does not delete or change the design section.

## 2.3 Design and Check Stations

For each design combination, steel joist beams are designed (optimized) or checked at a number of locations (stations) along the length of the object. The stations are located at equally spaced segments along the clear length of the object. By default, the stations in a beam will be spaced at most 2 ft apart (0.5 meter if the model has been created in SI units). The user can overwrite the number of stations in an object before the analysis is made using the **Assign** menu. The user can refine the design along the length of a member by requesting more stations.

## 2.4 Demand/Capacity Ratios

Determination of the controlling D/C ratios for each steel joist indicates the acceptability of the member for the given loading conditions. The steps for calculating the D/C ratios are as follows:

- The factored axial, flexural, and shear forces are calculated at each defined station for each design combination. The bending moments are calculated about the principal axes.

- The nominal strengths are calculated for compression, tension, bending and shear based on the equations provided later in this manual. For flexure, the nominal strengths are calculated based on the principal axes of bending.
- The nominal strength for shear is calculated along the geometric axes of the sections.
- Factored forces are compared to nominal strengths to determine D/C ratios. In either case, design codes typically require that the ratios not exceed a value of one. A capacity ratio greater than one indicates a member that has exceeded a limit state.

## 2.5 Design Load Combinations

The design load combinations are the various combinations of the prescribed analysis cases for which the structure needs to be checked. The program creates a number of default design load combinations for steel frame design. Users can add their own design combinations as well as modify or delete the program default design load combinations. An unlimited number of design load combinations can be specified.

To define a design load combination, simply specify one or more analysis cases, each with its own scale factor. The scale factors are applied to the forces and moments from the analysis cases to form the factored design forces and moments for each design load combination.

For normal loading conditions involving static dead load (DL) and live load (LL), the program has built-in default design combinations for the design code. These are based on the code recommendations.

The default design combinations assume all static load response cases declared as dead or live to be additive.

The program allows live load reduction factors to be applied to the member forces of the reducible live load case on a member-by-member basis to reduce the contribution of the live load to the factored responses.

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## Chapter 3

# Design Using SJI-2010

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This chapter provides a detailed description of the algorithms used by the programs when the menu option “SJI-2010” is selected for use in the design/check of structures in accordance with “SJI-K-2010—For Open Web Steel Joists, K-Series” and “SJI-LH/DLH-2010 — For Longspan Steel Joists, LH-Series and Deep Longspan Steel Joists, DLH-Series.” The implementation covers load combinations from “ASCE/SEI 7-10,” which is described in the section “Design Loading Combinations” in this chapter.

For referring to pertinent sections of the corresponding code, a unique prefix is assigned for each code.

- Reference to the SJI-K-2010 and SJI-LH/DLH-2010 code is identified with the prefix “**SJI**.”
- Reference to the ASCE 7-10 code is identified with the prefix “**ASCE**.”

### 3.1 Design Preferences

The steel joist design preferences are basic assignments that apply to all of the steel joist members. Table 3-1 lists steel frame design preferences for “SJI-2010.” Default values are provided for all preference items. Thus, it is not necessary to specify or change any of the preferences. However, at least review the default values to ensure they are acceptable. Some of the preference items also

are available as member-specific Overwrite items. The overwrites are described in the next section. Overwritten values take precedence over the preferences.

For purposes of explanation, the Preference items are presented in Table 3-1. Refer to the program Help for more information about Preferences.

**Table 3-1: Steel Joist Design Preferences**

Item	PossibleValues	Default Value	Description
Design Code	Design codes available in the current version	SJI-2010	The selected design code. Subsequent design is based on this selected code.
Design Provision	ASD, LRFD	LRFD	Application provisions for calculation of allowable/design and required strength of individual elements.

## 3.2 Overwrites

The steel joist design Overwrites are basic assignments that apply only to those elements to which they are assigned. Table 3-2 lists steel joist design overwrites for "SJI-2010."

**Table 3-2 Steel Joist Design Overwrites**

Item	PossibleValues	Default Value	Description
Current Design Section	Any defined steel joist section	Analysis section	The design section for the selected joist object. When this Overwrite is applied, any previous auto select section assigned to the frame object is removed.
Live Load Limit, L/	$\geq 0$	360	Deflection limit for superimposed live load. Inputting 360 means that the limit is L/360. Inputting zero means no check will be made of this item.
Live Load Reduction Factor	$\geq 0$	Calculated	The reducible live load is multiplied by this factor to obtain the reduced live load for the frame object. Specifying zero means the value is program determined.
Ignore Similarity?	Yes/No	No	This item is Yes if story level similarity (to a master story level) is to be ignored when designing the joist.

Default values are provided for all Overwrite items. Thus, it is not necessary to specify or change any of the Overwrites. However, at least review the default values to ensure they are acceptable. When changes are made to Overwrite

items, the program applies the changes only to the elements to which they are specifically assigned. Overwritten values take precedence over the Preferences. Refer to the program Help for more information about Overwrites.

### 3.3 Design Loading Combinations

The structure is to be designed so that its design strength equals or exceeds the effects of factored loads stipulated by the applicable design code. The default design combinations are the various combinations of the already defined load cases, such as dead load (DL) and live load (LL).

SJI-2010 specifications refer to the applicable building code for the loads and load combinations to be considered in the design, and to ASCE 7-10 in the absence of such a building code. Hence, the default design combinations used in the current version are the ones stipulated in ASCE 7-10:

For design in accordance with LRFD provisions:

1.4 DL	(ASCE 2.3.2-1)
1.2 DL + 1.6 LL	(ASCE 2.3.2-2)

For design in accordance with ASD provisions:

1.0 DL	(ASCE 2.4.1-1)
1.0 DL + 1.0 LL	(ASCE 2.4.1-2)

The combinations described herein are the default loading combinations only. They can be deleted or edited as required by the design code or engineer-of-record. The program allows live load reduction factors to be applied to the member forces of the reducible live load case on a member-by-member basis to reduce the contribution of the live load to the factored responses.

### 3.4 Steel Joist Properties

Steel joist property database files are provided as part of the installation of the program. The joist sections available in the database include the K-Series, KCS-Series, LH-Series and DLH-Series as defined by the Steel Joist Institute (SJI). Alternatively, users can define joist sections.

Two types of joist design capacities are considered by the program: Standard and Envelope design. Standard design is based on specified total uniform load capacities and live uniform load capacities for a range of spans. Envelope design is based on specified moment and shear capacities and a specified moment of inertia that is used to calculate deflection.

The K-Series, LH-Series and DLH-Series joists use the Standard design capacities. The KCS-Series joists use the Envelope design capacities. User specified joists can use either Standard design or Envelope design. Each of the design types is described in more detail later in this chapter.

### 3.4.1 Joist Properties for Standard Design

For Standard design, a series of joist spans is specified along with a total load capacity for each span and a live load capacity that produces an  $L/360$  deflection for each span. In addition, a moment of inertia is provided for each span. This moment of inertia is used only when reporting the joist deflection; it is not actually used in the design of the joist.

The joist depth item is specified but is not currently used in the design. The joist unit weight is used both to calculate an area for the section that is in the analysis, and to optimize the design when auto select section lists are used. The optimum joist is the lightest joist that passes all of the design checks. The *Analysis I33* item is used as the moment of inertia for the joist in the analysis.

### 3.4.2 Joist Properties for Envelope Design

For Envelope design a moment and shear capacity are specified along with a minimum and maximum span for which the joist will be designed.

The joist depth item is specified but is not currently used in the design. The joist unit weight is used both to calculate an area for the section that is in the analysis and to optimize the lightest joist that passes all of the design checks. An *Analysis I33* item is used both as the moment of inertia for the joist in the analysis and also to calculate the joist deflection, both for design checks and when the joist deflection is reported in Interactive Steel Joist Design and Review.



## 3.5 Design Checks for Standard Design

### 3.5.1 Joist Span

The joist span used to determine the capacity of K-Series and User joists is the full center-of-support to center-of-support span.

For LH-Series and DLH-Series joists, the joist span is taken as the full center-of-support to center-of-support span minus 8 inches.

### 3.5.2 Total Load Check

For the total load check, the program calculates the ratio of the maximum total uniform load acting on the joist divided by the total uniform load capacity of the joist. This ratio is reported in the output.

### 3.5.3 Live Load Check

For the live load check, the program first calculates the uniform live load capacity using Equation 1.

$$\text{LL Capacity} = \text{L/360 Capacity} * (360 / \text{LL Deflection Limit}) \quad \text{Eqn. 1}$$

where,

LL Capacity = Maximum uniform live load capacity

L/360 Capacity = Uniform live load capacity specified for the joist span in the joist section properties

LL Deflection Limit = Live load deflection limit specified in the overwrites

The program then calculates the ratio of the maximum uniform live load acting on the joist divided by the uniform live load capacity of the joist. This ratio is reported in the output.

### 3.5.4 Design of Joists When the Load is Not Uniform

For Standard design, the program checks if the applied load is uniform. If the load is not uniform, the design section is displayed with SP appended to its name.

The program uses the following method to determine if the load applied in a particular design load combination is uniform.

1. Find the maximum moment in the joist.
2. Calculate the uniform load that produces this maximum moment.
3. Calculate the moment cause by the uniform load calculated in Step 2 at each design output station along the joist.
4. Compare the actual moments obtained from the analysis at each design output station with the moments calculated in Step 3. If any of the moments differ by more than 5%, the load is reported as not uniform.

When the load is not uniform, the program uses an equivalent uniform load to determine the design ratios. The equivalent uniform load is the one calculated in Step 2 and is equal to  $8 * M_{max} / \text{Span}^2$ .

## 3.6 Design Checks for Envelope Design

### 3.6.1 Moment Capacity

For the moment capacity check, the program calculates the ratio of the maximum moment anywhere in the joist divided by the moment capacity of the joist. This ratio is reported in the output.

### 3.6.2 Shear Capacity

For the shear capacity check, the program calculates the ratio of the maximum shear in the joist divided by the shear capacity of the joist. This ratio is reported in the output.

The program also checks that the largest point load anywhere on the joist does not exceed the shear capacity of the joist.

### 3.6.3 Live Load Deflection Check

For the live load deflection check, the program calculates the ratio of the actual maximum live load deflection, calculated using the *Analysis I33*, divided by the live load deflection limit specified in the steel joist overwrites.

### 3.6.4 Maximum Equivalent Uniform Load Check

For Envelope design, the program checks that the maximum equivalent uniform load on the joist does not exceed 550 plf. The maximum equivalent uniform load is equal to  $8 * M_{max} / \text{Span}^2$ , where  $M_{max}$  is the maximum moment and Span is the joist span.

## 3.7 Data Plotted Directly on the Model

### 3.7.1 Overview

The onscreen data display is plotted directly on the model. The screen graphics also can be printed. Please refer to the program Help for information about displaying design information on the model and printing graphics or reports.

The on-screen display data is organized into three data groups, as follows.

- Labels
- Design Data
- Design Ratios

Each of those data groups is described in more detail later in this chapter. It is important to note that items from different data groups cannot be displayed simultaneously.

When design information is displayed directly on the model, the frame elements are displayed in a color that indicates the value of their controlling ratio. (Note that this controlling ratio may be a flexural, shear or live load deflection ratio.) Please refer to the program Help for more information about specifying display colors.

### 3.7.2 Labels Displayed on the Model

Beam labels and associated beam design group labels can be displayed on the model. A beam label is the label that is assigned to the frame object that represents the steel joist.

### 3.7.3 Design Data

The following design data can be displayed on the model:

- Joist section (e.g., 16K3)
- Joist end reactions

One or both of these items can be displayed at the same time.

### 3.7.4 Design Ratios

The following design data can be displayed on the model:

- Controlling ratio
- Controlling ratio type

The controlling ratio is the maximum design ratio obtained for the joist. The controlling ratio type is either flexure, shear or LL Deflection, indicating the type of design check that yielded the maximum design ratio.

### 3.7.5 Steel Joist Design Check Messages

This output is displayed on the model and in the printed output when the program is unable to design a particular joist. The check messages, such as CHK#2, are a "shorthand" way of indicating the design problem.

In the printed Steel Joist Detailed Output and the output obtained from the Interactive Steel Joist Design and Review form, descriptive messages are provided along with the shorthand messages. In the printed Summary of Steel Joist Output and for display on the model, only the shorthand messages are provided. Table 3-3 shows the descriptive messages that correspond to the shorthand check messages.

**Table 3-3 Steel Joist Design Check Messages**

<b>OUTPUT ITEM</b>	<b>DESCRIPTION</b>
CHK# 1	Error: No section in the auto select list is adequate for this joist.
CHK# 2	Error: The element is not designed because it is not a joist section.
CHK# 3	Error: This joist is not designed because there is negative moment.

**Table 3-3 Steel Joist Design Check Messages**

<b>OUTPUT ITEM</b>	<b>DESCRIPTION</b>
CHK# 4	Error: This joist is not designed because the equivalent uniform load exceeds 550 plf.
CHK# 5	Error: This joist is not designed because a single concentrated load exceeds the shear capacity.
CHK# 6	Error: This joist is not designed because no load data exists for spans this short.
CHK# 7	Error: This joist is not designed because no load data exists for spans this long.

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