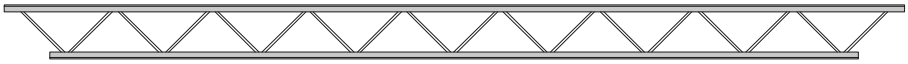
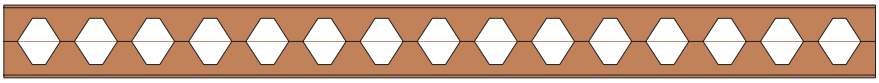
CISC Steel Design Series

Lightweight Steel Framing Solutions





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CISC Steel Design Series

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This Steel Design Series is prepared and published by the Canadian Institute of Steel Construction as part of a continuing effort to provide current and practical information for educators, designers, fabricators, and others interested in the use of steel in construction.

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LIGHTWEIGHT STEEL FRAMING SOLUTIONS

1. Introduction

Lightweight steel framing is commonly used in commercial and residential building projects. Applications favouring lightweight framing include long-span beams where the use of lighter sections can improve material economy, as well as bays with closely spaced members and relatively light gravity loads.

This publication will focus mainly on floor and roof members, and the following framing systems will be considered:

- Open-web steel joists (OWSJs)
- Castellated and cellular beams
- Cold-formed joists
- Fabricated hot-rolled beams
- Corrugated web beams
- Trusses

The choice of structural system can be influenced by several factors, such as the specific application, building location, cost, construction speed, and current supply conditions.

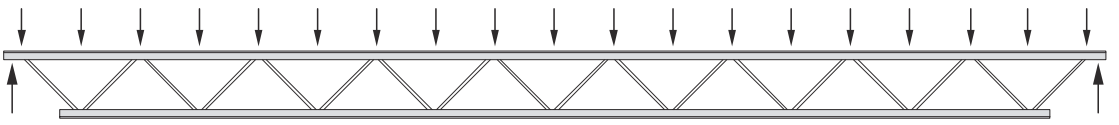
The above-mentioned systems can accommodate a variety of deck/slab options including cold-formed steel decks with or without a concrete cover slab. The Canam (2006) and Vulcraft (2020) catalogs can be consulted for further information.

2. Open-Web Steel Joists

2.1 Description

Open-web steel joists (OWSJs) are generally proprietary products that are designed, manufactured, transported and erected in accordance with the requirements of CSA S16, *Design of steel structures,* Clause 16. See CISC (2021a).

As illustrated in Figure 1, OWSJs are composed of top and bottom chords usually consisting of back-to-back double angles, which are held in place by diagonal web members (typically round bars) welded to the chords.



Open-Web Steel Joist
Figure 1

The use of lightweight, long-span construction can sometimes lead to noticeable vibrations due to human activity. Design criteria aimed at controlling floor vibrations are provided by Murray *et al* (1997) and by the Applied Technology Council (1999). A design example is given in CISC (2021b).

2.2 Advantages/Features

OWSJs can be used as either floor or roof members. Together with the steel deck, they form a structural system that has often proven to be economical. According to Canam (2015), the main advantages of this system include:

- Efficient use of steel,
- Speed and ease of erection,
- Low self-weight of roof and floor construction, allowing for smaller columns and foundations (compared to a concrete structure),
- Larger bay dimensions, reducing the number of joists and columns, simplifying building erection, and providing greater floor plan layout flexibility,
- Maximum ceiling height providing for the passage of ducts through the joist web,
- Ease of adaptation for acoustical insulation systems,
- Long-term fire resistance of floor and roof construction, as established by Underwriters Laboratories of Canada (ULC).

Vulcraft (2019) may also be consulted for further information.

2.3 Canadian Producers/Suppliers

- Canam Buildings,
  https://www.canam-construction.com/en/construction-products/steel-joist/
- Vulcraft Canada, *https://vulcraft.com/DesignTools/CanadianDesignTools*
- CISC fabricators, *https://www.cisc-icca.ca/members-associates-directory/*

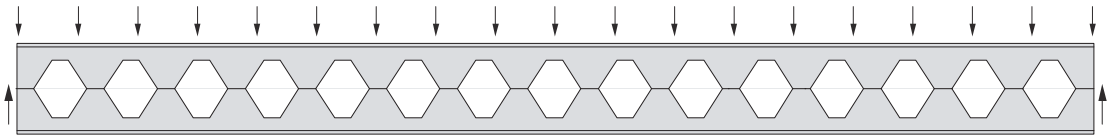
3. Castellated and Cellular Beams

3.1 Description

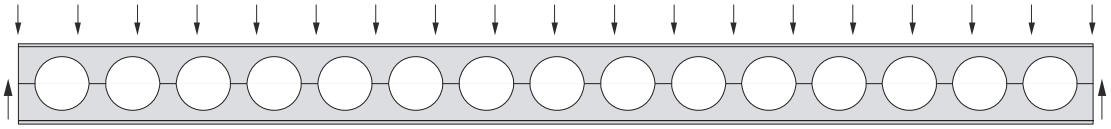
A castellated beam or cellular beam is in essence an I-beam longitudinally cut along its web following a specified pattern. The resulting cut sections divide the beam and reassemble it with a deeper web, taking advantage of the cutting pattern. The two different halves are offset and welded together to create a single expanded beam.

Castellated beams are filled with hexagonal holes and have hole limitations. Cellular beams use circular holes which reduce the overall number of holes and the amount of infilling, while providing various diameters of cells and a range of depths.

Cellular beams can also be produced from steel plates. The holes are cut out of a web plate which is then welded to two flange plates. With this form of "plate girder" fabrication, the size and thickness of the flanges and web can be optimized to meet loading, construction and opening requirements.



Castellated Beam
Figure 2a



Cellular Beam
Figure 2b

3.2 Advantages/Features

- Shallow floor-to-floor profile,
- Passage of ductwork (through or underneath shallow beams) facilitated by the hexagonal holes,
- Passage of natural light through the member,
- Easier hole alignment,
- Light and economical structure,
- Structural integrity similar to that of wide-flange solid-web beams,
- Efficient use of steel.

3.3 Canadian Producers/Suppliers

- CISC fabricators, *https://www.cisc-icca.ca/members-associates-directory/*
- CSSBI steel building systems manufacturers,
  https://www.cisc-icca.ca/cssbi-member-and-associate-directory/

4. Cold-Formed Joists

4.1 Description

Cold-formed joists generally consist of channel members that are manufactured from zinc or aluminum-zinc alloy-coated sheet steel. Coated sheet steel is supplied in the form of coils which the manufacturer will slit into different widths depending on the final products. The flat sheets are fed into a roll-forming mill, and the cold-formed channels are then cut to length. Unlike hot-rolled structural steel shapes, lightweight joists are produced at room temperature, thus the name "cold-formed".

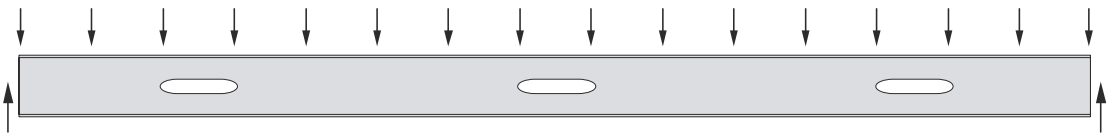
The high strength-to-weight ratio of cold-formed steel provides strong loading capacity and maximum spanning capability. Cold-formed steel joists can be used with all types of traditional flooring materials, such as plywood, oriented strand board (OSB), concrete-filled steel decking, or one of the many varieties of fibre-reinforced cement board. A factory-punched-web floor-joist system is ideal for running mechanical, plumbing and electrical services.

4.2 Types of Cold-Formed Joists

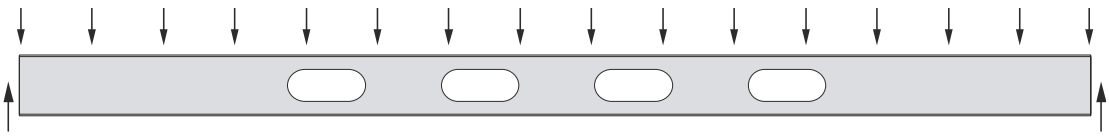
The two main types of cold-formed joists are:

a) Standard stiffened C-sections, without large holes in the web, and

b) Speciality patented I-sections, with large holes in the web.



Cold-Formed Joist, C-Section
Figure 3a



Cold-Formed Joist, I-Section
Figure 3b

4.3 Advantages/Features

- Shallow floor-to-floor profile,
- Web holes to accommodate, plumbing, mechanical and electrical services,
- Strong loading capacity and spanning capability compared to other materials,
- Composite design similar to that of wide-flange solid-web beams,
- Different types of flooring and roofing systems such as plywood, oriented strand board (OSB), cement-bonded particle board, steel deck with concrete,

- Non-composite and composite concrete flooring and roofing systems,
- Fire-rated assemblies in accordance with ULC M520, M521, I527 or I530.

4.4 Canadian Producers/Suppliers

- CSSBI steel stud, track and joist manufacturers certified to CSSBI 61:21,
  https://www.cisc-icca.ca/cssbi-member-and-associate-directory/
- CSSBI steel building systems manufacturers certified to CSA A660-10,
  https://www.cisc-icca.ca/cssbi-member-and-associate-directory/
- iSpan Systems,
  https://www.ispansystems.com/

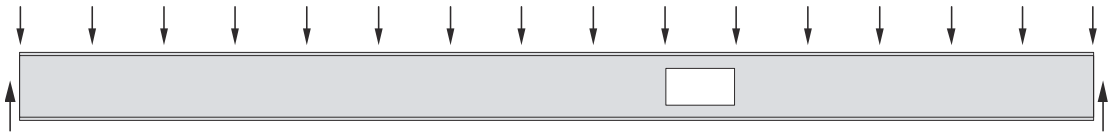
5. Fabricated Hot-Rolled Beams

5.1 Description

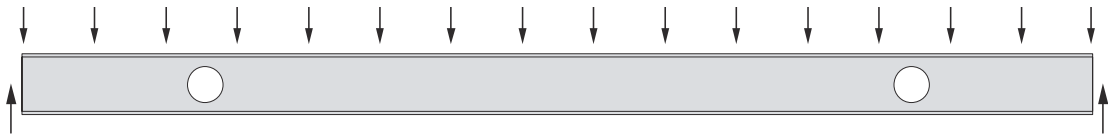
Wide-flange W-shape beams and girders are commonly used for floor construction, while C-shape channels are occasionally used as roof purlins in some applications. Although not necessarily classified as lightweight members, hot-rolled sections are sometimes used as an alternative to open-web steel joists.

Because of their greater capacity than some lightweight systems, hot-rolled sections may require a wider beam spacing and a stronger (and heavier) deck to achieve a comparable level of economy. These members are designed for the ultimate, serviceability and fatigue limit states in accordance with CSA S16:19, *Design of steel structures*.

In order to reduce the storey height, web openings can be provided to allow for the passage of service ducts, as illustrated in Figure 5. Depending on the size and location of the openings, reinforcement may be required. Design examples can be found in CISC (2021a).



W-Shape Beam with Rectangular Web Opening
Figure 4a



W-Shape Beam with Round Web Opening
Figure 4b

5.2 Advantages/Features

- Greater flexural strength and stability for long-span applications and heavy loads,
- Wide range of available sections, properties and dimensions,
- Ease of connection using bolted or welded joints,
- Readily available and commonly used products throughout North America,
- Well defined and standardized design capacity for both laterally supported and unsupported members,
- Composite behaviour and greater capacity achievable through the use of welded shear studs,
- ULC (Underwriters Laboratories of Canada) and cUL (UL standards approved for the Canadian market) fire-rated assemblies.

5.3 Canadian Producers/Suppliers

- CISC fabricators, *https://www.cisc-icca.ca/members-associates-directory/*

6. Corrugated Web Beams

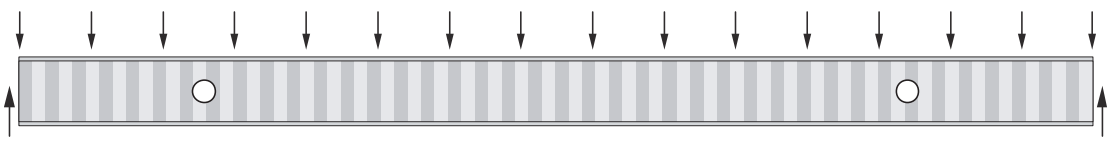
6.1 Description

Corrugated web beams, also referred to as SIN beams (*sinusoidal webbed beams*), are generally created by an automated process to produce corrugated steel web plates from cold-formed sheet steel, which are then fitted and welded to hot-rolled top and bottom flanges.

SIN beams are typically used in lieu of hot-rolled sections as structural beams supporting the roof or floor systems. Because of their greater capacity than some lightweight systems, corrugated web sections may require a wider beam spacing and a stronger deck to achieve a comparable level of economy. Lateral stability is typically achieved by top flange connection to the diaphragm and by the intermediate members attached to the web.

The top and bottom flanges provide compressive and tensile resistance for overall bending, while the corrugated web resists shear forces. These members are designed in accordance with CSA S16:19, *Design of steel structures* and CSA S136-16, *North American specification for the design of cold-formed steel structural members*.

In order to reduce the storey height, web openings can be provided to allow for the passage of service ducts, as illustrated in Figure 5.



Corrugated Web Beam
Figure 5

6.2 Advantages/Features

- Substantial weight savings compared to hot-rolled sections, allowing for thinner webs without the need for shear stiffeners,
- Automated production resulting in high-quality welding and assembly,
- Standard heights from 333 mm to 1500 mm with standard sine wave of 155 mm,
- Optional web openings, which may require reinforcement,
- Connections to the flanges or web, including splice plates and end plates,
- Unique formulas for shear capacity,
- Thirty years of use overseas.

6.3 Canadian Producers/Suppliers

- Steelcon Fabrication Inc., *https://www.steelcon.ca/*

7. Trusses

7.1 Description

Steel trusses consist of triangulated or rectangular systems composed of straight interconnected structural elements. They are normally designed to carry axial forces in their members, which act either in tension or compression, or in reversible tension/compression depending on the most severe load cases. Trusses are fabricated by bolting or welding standard sections together, with the joints designed as pins.

The top and bottom chords provide the compressive and tensile resistance to overall bending, while the web or diagonal bracing elements resist the shear forces. Structural design provisions are given in CSA S16:19 Clause 15 for non-composite trusses, with additional information given in Clause 17 for composite trusses.

7.2 Types of Trusses and Member Sections

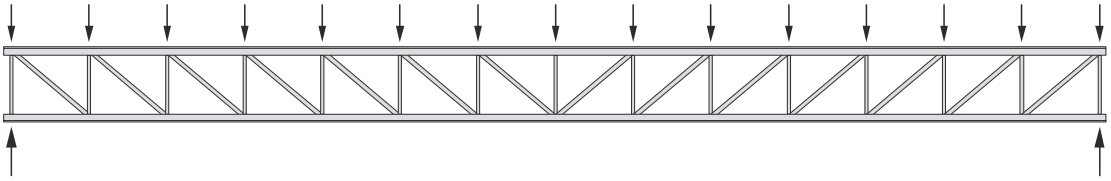
A wide variety of truss forms can be created, varying in overall geometry and in the choice of individual components. The major types of trusses are parallel-chord (see Figure 6), pitched-chord and trapezoidal trusses. The choice of configuration will depend on the span and type of building.

For spans up to 20 m, angles, tees and light hollow sections can be used for the member sections, as shown in Figure 7. For longer spans, heavier hot-rolled sections may be required. The mixed use of these sections may help minimize the visual impact of the diagonal bracing members, which are typically lighter than the chords.

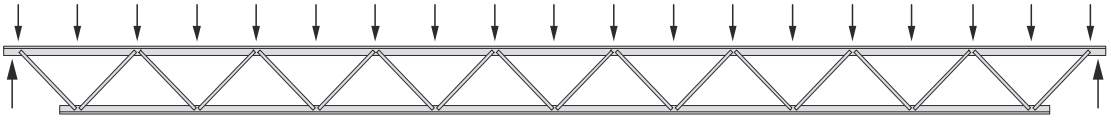
7.3 Advantages/Features

- Very efficient use of steel,
- Aesthetic/elegant structural solutions for long-span roofs using hollow structural sections,
- "Transfer structures" for supporting floors above and creating open areas below,
- Open concept with fewer internal columns and reduced foundations,

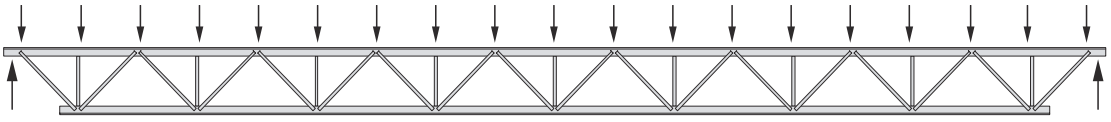
- Outstanding strength-to-weight ratios,
- Economy, ease of erection in nearly any weather, high durability and unlimited flexibility,
- Passage of mechanical, electrical and plumbing services (ducts, cable trays, piping, etc.),
- Customized fabrication to suit unique and specific needs,
- Increased durability and fire resistance due to non-combustible properties.



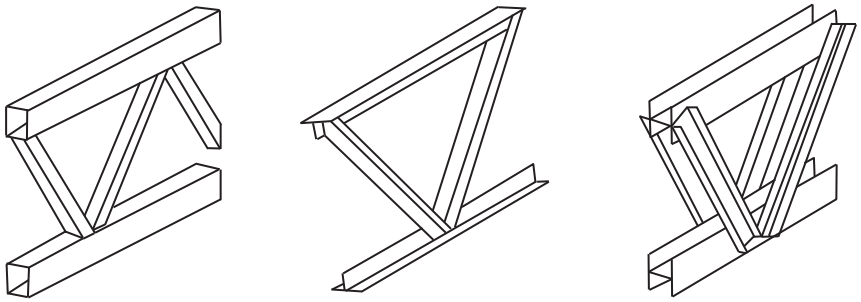
Pratt Truss
Figure 6a



Warren Truss
Figure 6b



Modified Warren Configuration
Figure 6c



Basic Configurations
Figure 7

7.4 Canadian Producers/Suppliers

- CISC fabricators, *https://www.cisc-icca.ca/members-associates-directory/*

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