Trusses

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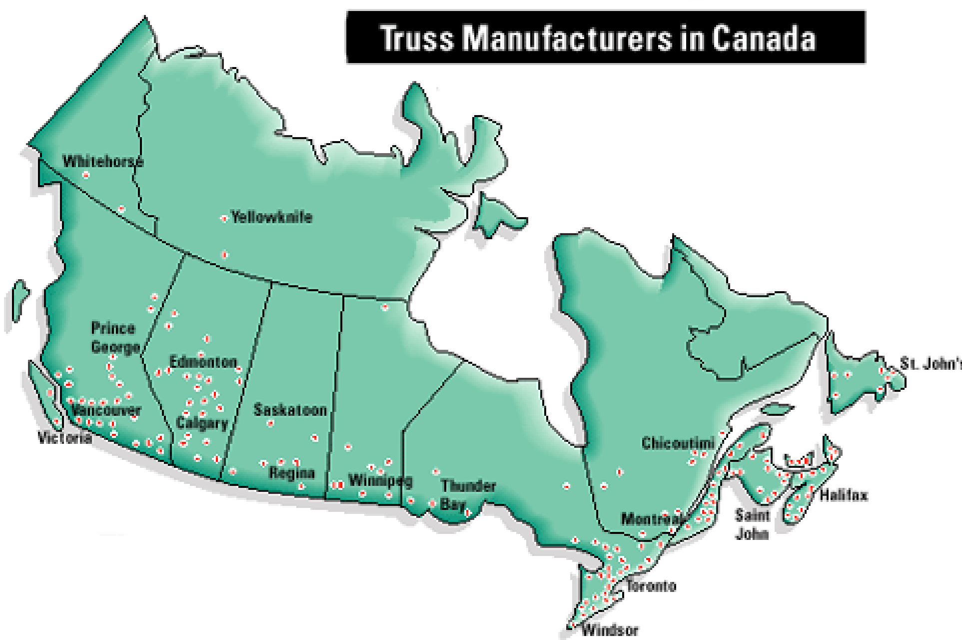
Introduction

Wood trusses are widely used in single- and multi-family residential, institutional, agricultural and commercial construction. A truss is a structural frame relying on a triangular arrangement of webs and chords to transfer loads to reaction points. This arrangement gives them high strength- to-weight ratios, which permit longer spans than conventional framing, and offers greater flexibility in floor plan layouts. They can be designed in almost any shape or size, restricted only by manufacturing capabilities, shipping limitations and handling considerations. Light frame wood trusses are prefabricated by pressing galvanized steel truss plates into wood members that are pre-cut and assembled in a jig.

In Canada, most new houses are built with wood roof trusses. It's not surprising considering their:

- **Strength:** Trusses provide a strong and efficient structural wood system specifically engineered for each application.
- **Economy:** Through efficient use of wood and by providing a system that is installed in as little as half the time of conventional wood framing, wood trusses provide an economical framing solution.
- **Versatility:** Complex shapes and unusual designs are easily accommodated using wood trusses.
- **Environmental Benefits:** Wood, the only renewable framing material, has numerous environmental advantages. Wood trusses enhance wood's environmental advantages by optimizing wood use for each specific application. For more information see www.cwc.ca/environment/

The Canadian truss industry is comprised of truss plate manufacturers, truss fabricators and several associations. In 1972, truss plate manufacturers in Canada formed the Truss Plate Institute of Canada (TPIC) whose responsibilities include: : representation in building codes and standards and development of standards for truss design, manufacturing and quality control. There are also a number of regional fabricator associations in British Columbia, Alberta, Saskatchewan/Manitoba, Ontario, Quebec and Atlantic Canada.



The Canadian Wood Truss Association (CWTA) is a national organization representing truss fabricators whose mandate is to develop and maintain uniform performance standards, foster training and educational activities for it's members and business partners, represent the industry with its peers and defend the interests of the industry.

In the United States the Truss Plate Institute (TPI) was formed in 1960 to maintain an industry wide truss design standard and the Wood Truss Council of America (WTCA) is the trade association representing structural wood component manufacturers.

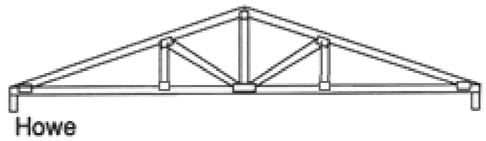
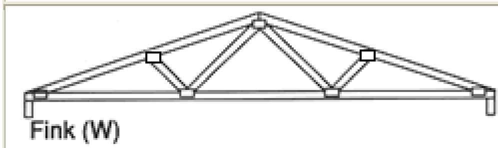
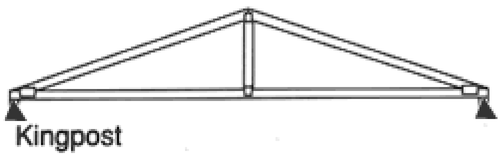
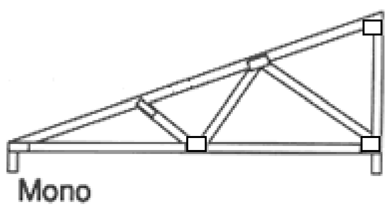
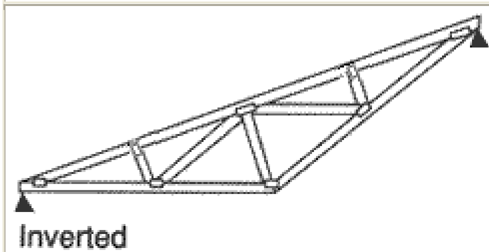
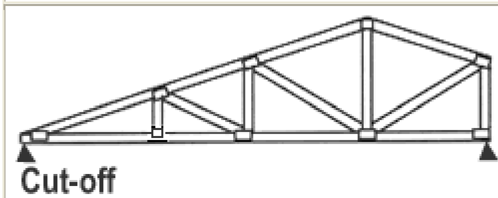
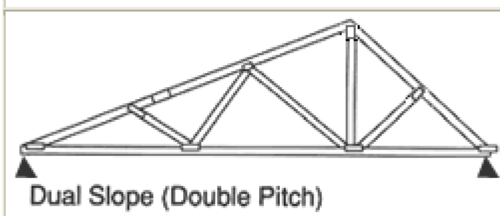
Applications

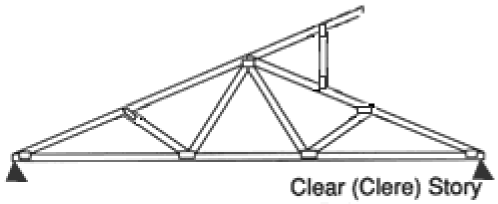
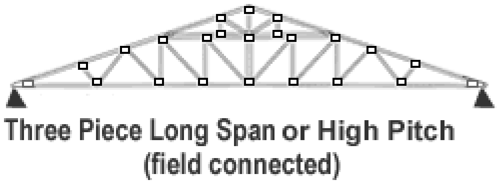
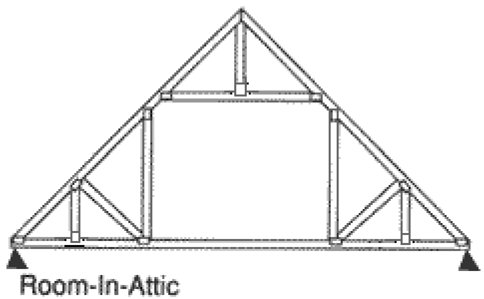
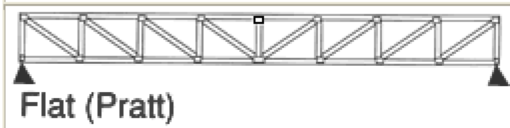
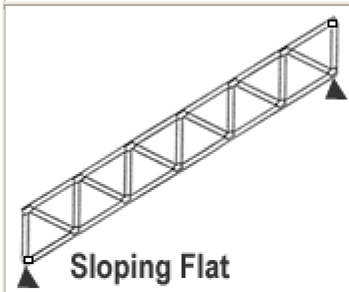
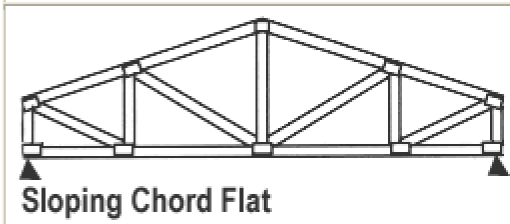
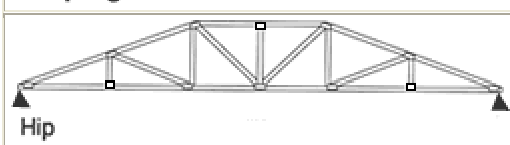
Long spans without intermediate supports create large open spaces architects and designers can use with complete freedom. Partitions can be moved without compromising the structural integrity of the building. Framing a roof with wood trusses can be accomplished in half the time required for a conventional rafter based system. In addition to flexibility and cost effectiveness trusses are used for the following reasons:

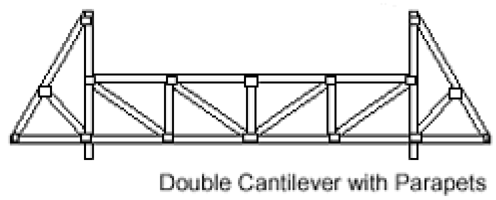
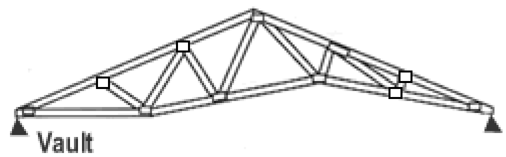
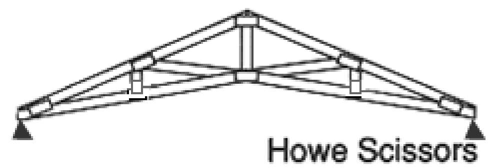
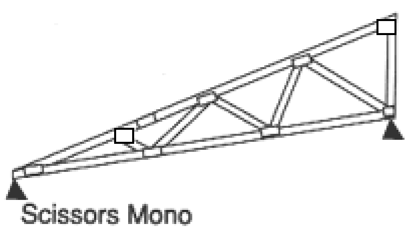
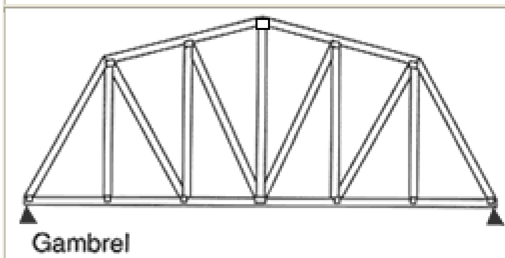
1. Truss shapes have almost unlimited variety, thus allowing for distinctive roof shapes.
2. Many restaurant chains choose to expose their corporate identity in the prefabricated metal plate connected wood truss roof design of their buildings.
3. Metal plate connected trusses are used to create arches of all types.
4. Wood trusses used in specialized applications such as agricultural and commercial buildings provide spans exceeding 25m (80').
5. As a testament to their strength, wood trusses are used in concrete formwork, scaffolding and falsework for industrial projects.
6. The open web configuration of roof and floor trusses allows easy placement of plumbing, electrical, mechanical and sanitary services.
7. Vaulted ceilings are easily made: bottom chords of pitched trusses can be sloped, or parallel chord pitched trusses bearing on supports at different elevations can be used. Attic trusses are designed to provide living areas within the roof space.
8. Wood trusses are very versatile and compatible with other structural products. They can be connected to other trusses (i.e. girder trusses) or combined with other components, such as glulam, LVL, PSL and steel beams. In North America, wood roof trusses are commonly supported on concrete or masonry walls using simply installed connections to join the roof to the walls.
9. Hinged connector plates used with mono-pitch trusses allow modular homes to be assembled with conventional roof pitches, greatly enhancing their appearance.

Shapes

Some of the most common truss shapes are shown below using industry terminology.

	Howe	These trusses may be simple span, multiple bearing, or cantilevered. Where the truss height exceeds approximately 3m (10'), a piggyback system (see below) may be needed due to transportation restrictions. (Height - Width restrictions vary by location for shipping. Also plants can be limited by equipment. Some jobs may be built one piece & shipped with an escort.)
	Fink	
	Triangular	
	Mono	This shape may be simple span, multiple span, or cantilevered. Top chord bearing is possible.
	Inverted	The inverted truss is used to provide a vaulted ceiling along a portion of the span.
	Cut-off (Bobtail, Stubend)	This shape may be used where a triangular truss will not fit. Usually stubbed at jogged exterior or at change to vaulted ceiling in opposite direction.
	Dual Slope	This truss provides an asymmetric roof slope.

	Ridge Truss	The ridge truss provides a stepped roof appearance.
	Piggyback (Three piece)	The piggyback truss is a combination of a gable end truss on top of a hip truss, which can be transported in two sections. It is used when a single triangular truss is too large to transport.
	Attic	The attic truss provides useable area within the roof space. Bottom Chord in centre designed as a floor.
	Flat or Parallel Chord	The flat truss is used in roofs or floors. It may be designed as top or bottom chord bearing, or for simple or multiple spans. It may also be cantilevered at one or both ends. They may be ordered with a built shallow slope to offset deflection and to provide positive drainage when used as a flat roof system.
	Sloping Flat	This shape is used to create a vaulted ceiling. It may be top or bottom chord bearing.
	Double Sloping Chord Flat	This shape is used to provide positive drainage to both sides of the building and is also referred to as a High Heel Common Truss.
	Hip	This shape is used to create hip roofs and is also referred to as a Step up Hip Truss.

	Mansard with Parapets	This truss is used to create a mansard roof profile.
	Cathedral	The cathedral truss provides a vaulted ceiling along one portion of the span.
	Scissor	The scissor truss is used to create a vaulted ceiling along the entire span. The slope of the bottom chord is usually equal to 1/2 of the slope of the top chord. Large scissor trusses are often shipped in two pieces and field spliced.
	Half Scissor	The half scissor truss provides a single-sloped vaulted ceiling.
	Gambrel	This truss is used to create a gambrel or barn-shaped roof profile.

Spans

The span capability of light frame trusses is dependent on loads, style, spacing, depth, lumber and plate properties. Sample spans are given below as guidelines for both floor and roof trusses.

Sample Canadian Spans for Parallel Chord Floor Trusses spaced at 400 mm		
	Sample Spans, m	
Depth mm	1.9 kPa Residential Floor Truss	2.4 kPa Office Floor Truss
300	Up to 6	Up to 5
400	6 - 8*	5 - 7
600	8 - 11*	7 - 10

* Residential spans exceeding 6 meters may be governed by vibration criteria

Specific loadings and other structural requirements must be clearly identified for proper design of any truss system. In designing the appropriate trusses, the truss manufacturer will incorporate these specifications with the architectural requirements. The span capabilities of trusses should be discussed with a truss manufacturer.

History

The first light frame trusses were built on site using nailed plywood gusset plates. These trusses offered acceptable spans but demanded considerable time to build. In the 1950's the metal connector plate transformed the truss industry by allowing efficient prefabrication of short and long span trusses. Originally developed in the United States, the truss plate is now the connector used in light frame trusses.

The popularity of this system grew rapidly since trusses could be prefabricated using highly efficient production techniques and machinery. Today economy, fast delivery and simplified erection procedures have made wood trusses competitive in many roof and floor applications in both long and short spans.

Materials

Lumber

Most trusses are fabricated using visually graded lumber and machine stress-rated lumber. Visual grades used in chords will include Select Structural, No.1/No.2, whereas webs can also use No. 3 and Stud gradesgrades. When calculated stresses and truss configurations require greater strength qualities machine stress-rated lumber is used. Trusses are fabricated using 38 x 64mm to 38 x 286mm lumber according to loading and truss spacing. All trusses for use in Canada must be manufactured using NLGA graded lumber that have assigned structural properties listed in CSA O86-01

Plates

Today, almost all light frame trusses are connected by means of galvanized steel plates referred to commonly as truss plates or connector plates. The plates are manufactured by high speed stamping machines that punch out the plate teeth, and shear the plate to required size. Many sizes and gauges of connector plates are manufactured to suit a variety of joint geometries and loadings. The use of metal plates permits the plant fabrication of trusses with consistent and dependable engineering properties.

The metal connector plate transfers loads between adjoining members through the connector plate teeth. The connector plate strength is dependent on the grip of the teeth and the shear and tensile capacity of the steel plate. The plate is prevented from deforming during installation, and the minimum tooth penetration must be maintained, as monitored by the manufacturer's quality assurance personnel. Each plate must be installed using specifically designed press or roller truss plate equipment to achieve published design values as per CCMC reports. Truss plates that are available to the public through retail outlets or those used by related industries in packaging & pallets will perform to published values only if installed correctly.

In Canada truss plates are usually stamped from 16, 18 or 20 gauge (US Standard Gauge) sheet steel of minimum quality as prescribed in the 2001 edition of CSA Standard O86-01, *Engineering Design in Wood*. Truss plates are proprietary products approved by the Canadian Centre for Materials in Construction (CCMC) each with a unique set of design values. In order to obtain approval, the plates are tested in accordance with CSA Standard S347-M1980 *Method of Test for Evaluation of Truss Plates Used in Lumber Joints*.

Plate widths can be from 25mm (1") to 300mm (12") and lengths can be up to 600mm (2') or even longer. Stamping results in teeth lengths varying from about 6mm (1/4") to 25mm (1"). Nail-on plates are occasionally provided to allow assembly by the builder on the site. For example, nail on plates are sometimes used to join separate parts of a field-assembled truss.

Design

Procedures

The truss design is initiated by the builder or owner, or his designate; i.e. the general contractor or architect/engineer. The documentation must include:

- the size of the building,
- the building occupancy,
- the shape and span of the truss,
- where the truss will be supported,
- the type of roof construction (finish, insulation, sheeting, ceiling type)
- what the loads on the truss will be
- special requirements to be considered in truss design such as special loading and placement
- geometry defining parameters (pitches, heel heights, overhang and cantilever details)

For more details on the design responsibilities of the truss designer and the building designer consult the TPIC design procedures page iii.

Typically, the building designer or builder will contract with the truss fabricator, who will supply a truss layout and a structural design of each significant element of the roof system. The truss plate manufacturer's engineer usually reviews and seals the individual truss designs on behalf of the truss fabricator.

In North America, designs are based on structural requirements from Building Codes using

design standards referenced in Building Codes and approved material properties:

- Structural analogues and methodology have been developed and standardized by National Associations such as TPIC in Canada and TPI in the United States who represent the manufacturers of metal plate connectors.
- Lumber design values for use in Canada are published by Canadian Standards Association (CSA 086-Engineering Design in Wood).
- Truss connector plates are proprietary and therefore come with different structural properties. Design values for truss plates are developed through tests and analyses in accordance with referenced standards. Approval of the design values is overseen by national certification organizations such as the Canadian Construction Materials Centre (CCMC).

Preliminary discussion of a design with a truss fabricator may result in suggestions leading to the most efficient and the most cost effective design.

Truss design is facilitated by the use of computer software that designs all members, connections and produces a design drawing for an engineer's approval and also shop drawings and cutting lists for manufacturing and quality control.

The approval and acceptance process of truss design drawings depends on local requirements. In most jurisdictions, a professional engineer's stamp on the truss design drawing may be compulsory. In other cases alternate procedures may be acceptable.

Codes and Standards

In Canada truss design is regulated by the provincial or territorial building codes. Design loads for trusses depend on the type of structure as referenced in the building code.

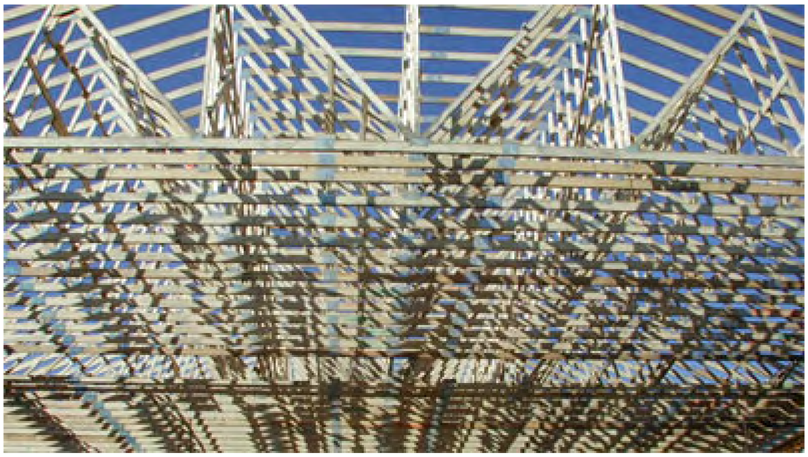
Trusses for houses and small buildings or Part 9 structures in Canada are designed in accordance with design procedures from TPIC Truss Design Procedures and Specifications for Light Metal Plate Connected Wood Trusses as per the National Building Code section 9.23.13.11.

Trusses for commercial or industrial buildings are governed by the requirements of Part 4 of the NBCC and are designed in accordance with CSA O86-01 which references the truss plate testing standard CSA S347 Method of Test for Evaluation of Truss Plates Used in Lumber Joints.

Trusses for agricultural buildings are also designed in accordance with Part 4 of the National Building Code and CSA O86. In some provinces some modifications for agricultural type structures are based on the Canadian Farm Building Code where it is accepted.

More information on truss design procedures can be found at:

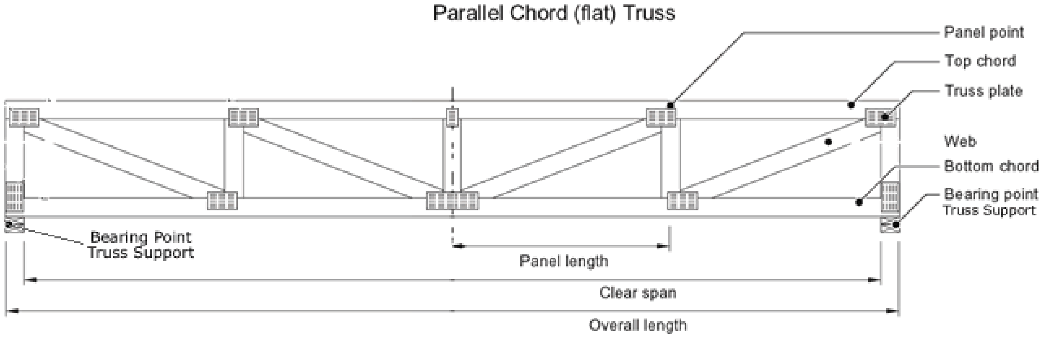
- TPIC Truss Design Procedures
- CSA Standard O86-01 Engineering Design in Wood



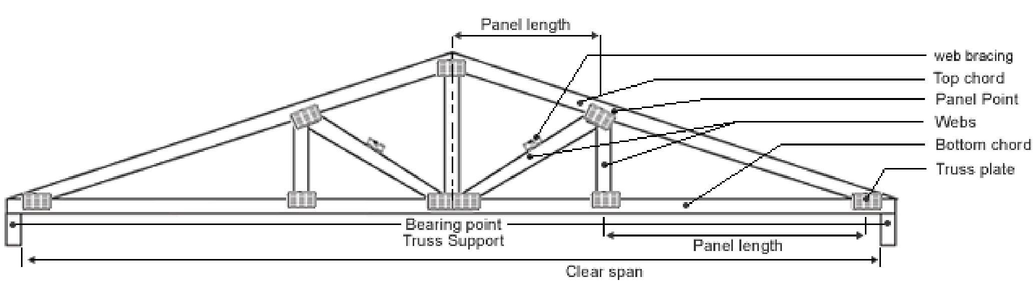
Truss Configurations

An understanding of truss geometry by the designer will assist in dealing with load paths imposed by the truss system. Trusses come in many configurations, which include parallel chord truss for floors and flat roofs and peaked trusses for typical roof applications. Trusses can also be stacked to support an infinite combination of roof profiles.

Parallel Chord (flat) Truss

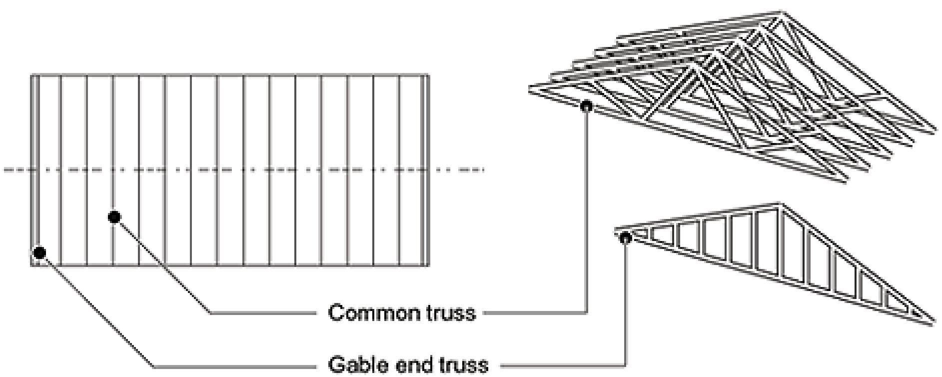


Pitched (triangular) Truss



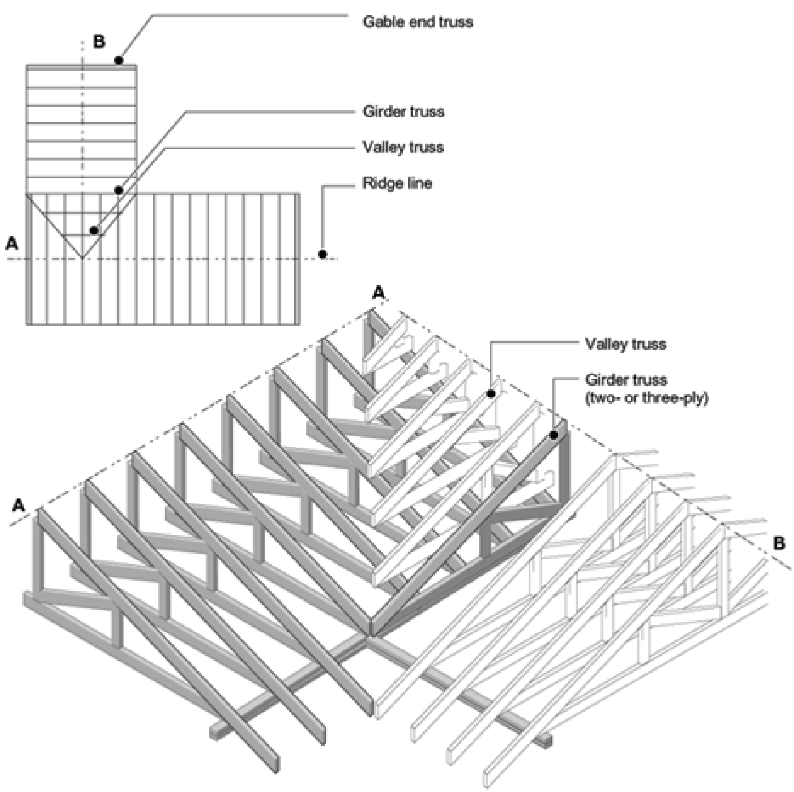
Gable roof truss system

A standard gable roof is the simplest arrangement, with gable end trusses at both ends and common trusses spaced in between. Gable end trusses sit on the end walls and carry roof loads directly into the wall below. Common trusses are designed to act as bending members spanning between the exterior walls.



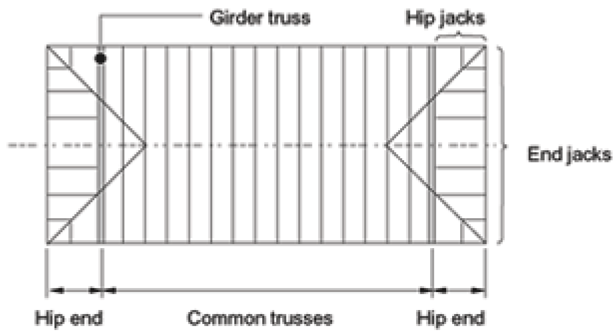
Girder and valley truss system

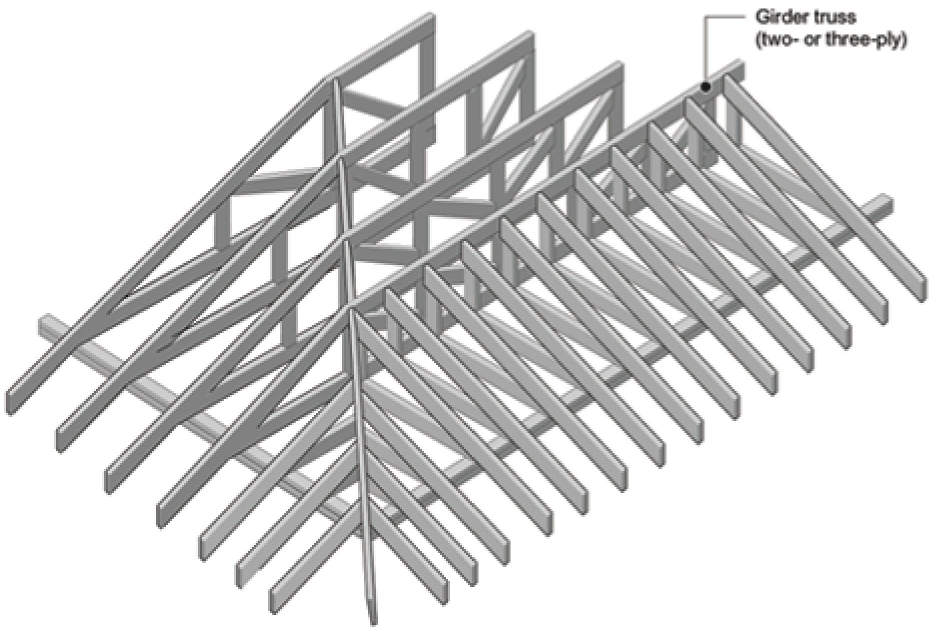
Buildings with intersecting ridge lines can be framed as shown below. Valley trusses are supported on top of the common trusses to form the intersecting ridge. If a clear span opening is required where the roofs intersect, a girder truss can be used to support the valley trusses and common trusses at the intersection. The girder trusses usually are specially made with heavier chords and plates and can consist of a number of trusses laminated with nails or bolts.



Hip roof system

A hip roof consists of two hip ends built up of flat top hip trusses in a step down system as illustrated below. In this system, common trusses are located between the two hip ends and the height of the hip trusses is decreased with each subsequent truss beyond peak of the hip. Hip ends are usually built from the end up starting with a multi ply hip girder.





Truss Support

The building designer/Structural Engineer of Record is responsible for the structure that supports the trusses including the support of the truss bracing system. Temporary and permanent bracings are essential components that require design and consideration when assessing costs. Additional information on bracing guidelines are provided in the bracing section. Bearing walls and lintels must be designed to resist the truss loads, including point loads from girders. The building designer should also ensure that all nails, hangers and uplift anchors between trusses and support framing are adequate. Typically prescriptive toe nailing requirements are given in Building Codes for smaller structures whereas metal uplift anchors are often used for larger buildings or in areas of high wind.

Preservative Treatment and Truss Plates

Special attention should be given to service conditions such as wet service and an associated treated service condition. Truss plates should not be used in incised lumber. Agricultural buildings can sometimes give rise to corrosive environments that require special measures such as a higher standard of galvanization such as a G185 coating class or even use of stainless steel truss plates instead of the typical G60 coating class used in the U.S. or G90 coating class used in Canada. As of January 2003 new preservatives such as Copper Quat ACQ or Copper Azole CBA-A or CA-B were introduced in the marketplace to treat wood. These may also require G185 coating class or stainless steel truss plates. Further guidance on the use of trusses in special environments may be available from your regional truss association.

Manufacturing

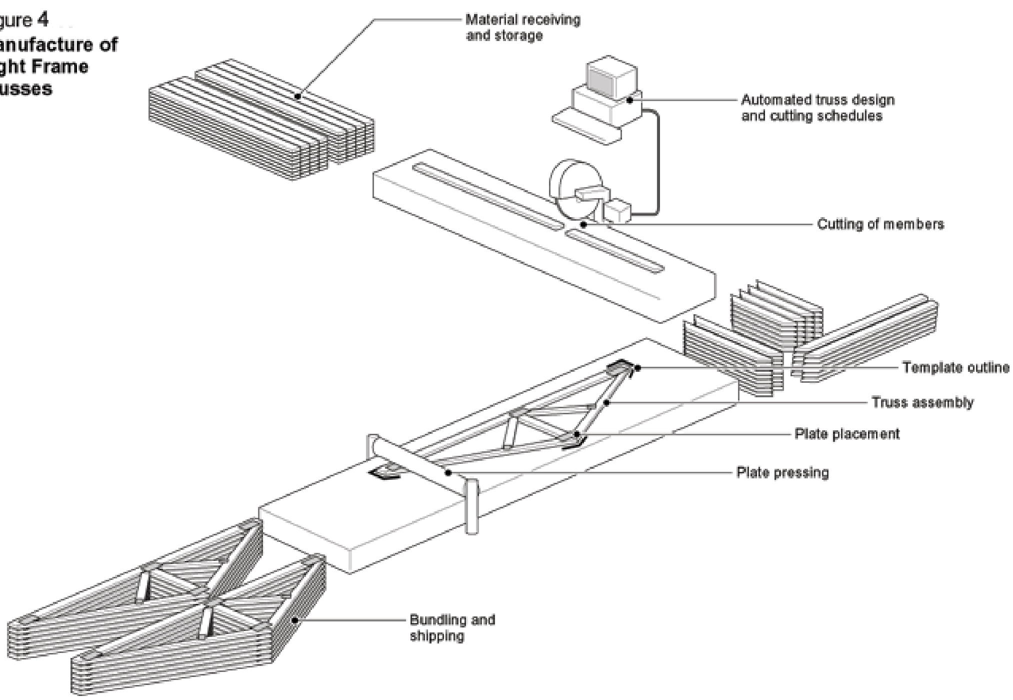
The computer design of light frame trusses results in the generation of fabrication instructions that indicate the precise cutting patterns for each of the members and the type, size, and location of connector plates required. A layout template is made for each configuration to ensure that like trusses are identical in dimension. The member pieces are cut to correct dimension and assembled in the template, which is located on a floor, truss jig, or heavy table.

The cutting drawings show a sketch of the truss and contain the following important information:

- overall truss dimensions
- location of all supports
- web and chord sizes and grades
- plate size, type, and location for each joint

The chords and webs are connected together by the use of truss plates, which transfer the tensile, compressive and shear forces. Identical truss plates are placed directly opposite each other on opposing faces and are pressed into the wood members using hydraulic platen (plates) presses or rollers.

Figure 4
Manufacture of Light Frame Trusses



When the pressing of the plates has been completed, the trusses are checked for dimensions, wood to wood gaps, lumber size and species, plate size, positioning and embedment and moved to a storage area. In some cases plants have a quality control program that ensures consistency in production and quality in place of checking each truss. The completed trusses are then strapped together and placed in the storage yard in preparation for shipping.

Quality Control

Criteria for design and use of light frame trusses are based on building code and engineering standard requirements. In Canada truss design is regulated by the provincial or territorial building codes that refer to the TPIC Truss Design Procedures and Specifications for Light Metal Plate Connected Wood Trusses In the US, the model building codes, the National Design Specification, and the Truss Plate Institute Standards govern design and quality control requirements.

In addition to the mandatory requirements for truss design and inspection established by code, many truss manufacturers belong to truss manufacturing associations that conduct on-site audits of design, manufacturing and handling procedures. In some cases trusses will display an Regional Association Certification Stamp indicating that the trusses were manufactured in a plant that complies with an Association Quality Certification Program.

It is important that building designers/Structural Engineers of Record/contractors review all truss drawings and installations to ensure that trusses are properly constructed and erected.

Fire Safety

Design requirements for fire safety are specified in the Building Codes. Fire-resistance ratings, based on standardized tests, are a measure of the fire resistance of roof and floor assemblies. A rated roof or floor truss assembly includes the truss members, the floor or roof sheathing on the upper surface, the ceiling finish on the lower surface and insulation material in the cavity. Depending on sheathing, ceiling construction, and insulation, truss assemblies have achieved fire resistance ratings up to 2 hours. Not all truss assemblies require a fire resistance rating. The building occupancy, the building size, number of exits and the use of sprinklers will determine what fire resistance rating is required. In some cases additional options may be available when using fire retardant treated wood. For more information on such products see www.dricon.com.

Section 10 of the Wood Reference Handbook outlines the code requirements for fire safety and height and area potential for buildings making use of light frame trusses. As well, details are provided on how to calculate the fire-resistance rating of floor and roof assemblies made of plate-connected wood trusses.

One example of a code requirement is the compartmentalization of attic spaces by fire stop material to divide them into spaces with an area of less than 300 m^2 or 20 m in greatest dimension (width/length). To accomplish this an additional truss sheeted with ½" gypsum board, lumber or 1/2" wood-based panels attached to verticals at 24" o.c. may be required. If the space is protected by automatic sprinklers, no firestopping is required

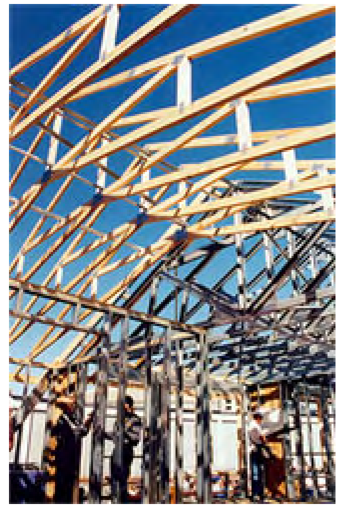
Floor truss assemblies can also be optimized to reduce sound transmission. In apartments, this limits noises from upper or lower units.

For more detailed information in the U.S consult the fire and Wood Trusses section of the WTCA website or the American Wood Council's publications on fire at http://www.awc.org/Codes/dcaindex.html#FirePubs

Other items of interest:

CMHC's Best Practice Guide - *Fire and Sound Control in Wood Frame, Multi-family Buildings* (On CHMC website, select "Building & Design" then "Highrise & Multi-Unit Design".)

CodeCHEK - CodeCHEK is a tool for determining fire safety provisions affecting building construction and requirements for roof assemblies and concealed spaces for Canadian building codes.



Links

Canada

Truss Plate Institute of Canada

Canadian Wood Truss Association

Western Wood Truss Association of B.C.

Western Wood Truss Association of Alberta

Western Wood Truss Association (MAN.SASK.NW ON)

Ontario Wood Truss Fabricators Association

Association Quebecoise des Fabricants de Structures de Bois

Atlantic Wood Truss Fabricators Association

United States

www.woodtruss.com

www.tpinst.org

Technical Information and Standards

Truss related Technical Bulletins

Truss Design Procedures and Specifications for Light Metal Plate Connected Wood Trusses
Limit States Design

Method of Test for Evaluation of Truss Plates Used in Lumber Joints CSA S347