Steel Roof Trusses

An Overview on Designing, Manufacturing, and Installing Roof Trusses

Most building roofs can be framed with engineered light-gauge steel trusses which are manufactured from C-Shaped metal studs. Prefabricated steel trusses offer a high-strength, light-weight roof system that can be installed quickly. Roofs on more than 20% of all new commercial structures in the United States are built with light-gauge steel trusses. In residential construction, wood trusses still dominate the industry, however light gauge steel roof systems are gaining ground in markets where additional strength is needed, or where greater free spans are required.

Scissor Truss (shown) provide a dramatic ceiling effect. This truss type will exert lateral forces on walls if not nstalled with a fixed and slide end.

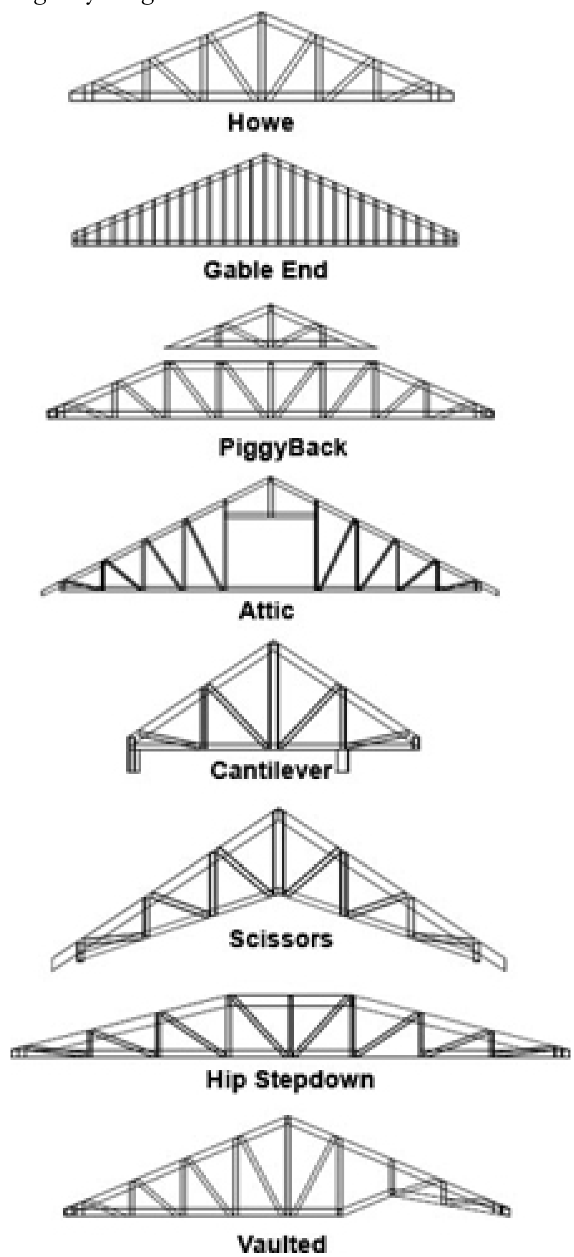
A standard truss is a series of triangles - a stable geometric shape that is difficult to distort under load. Regardless of its overall size and shape, all the chords and webs of a truss form triangles. These triangles combine to distribute the load across each of the other members, resulting in a light structure that is stronger than the sum of the strength of its individual components.

However, for all the advantages, proper installation techniques and bracing are critical. Additionally, trusses should not be modified in the field without consulting the truss manufacturer. Cutting a web member, for example will radically alter its strength.

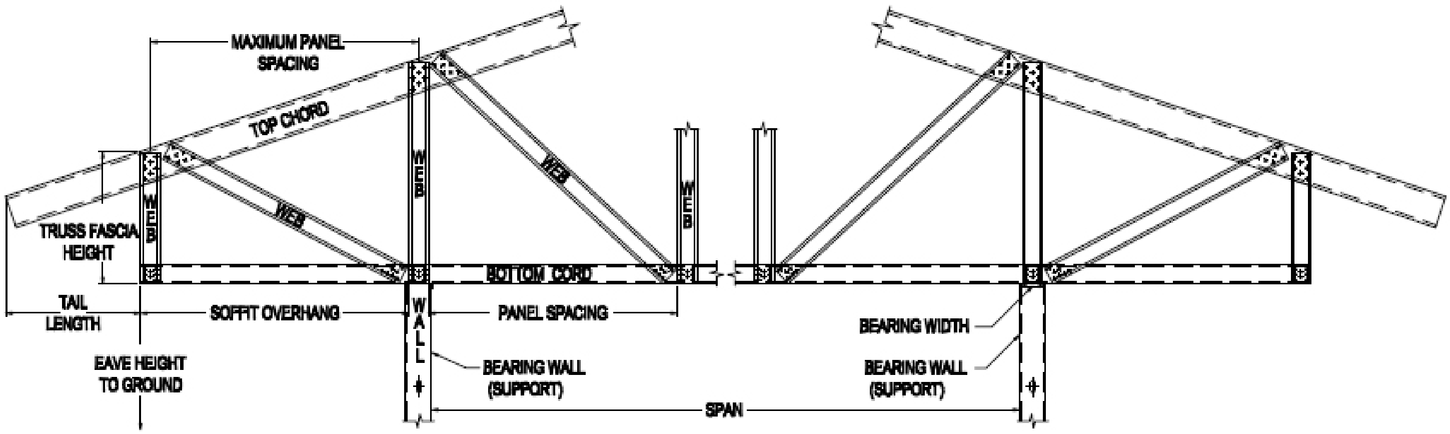
Truss Types

There are many truss types. The most common types are shown on the facing page.

Most roof trusses have webs that run at an angle between top and bottom chords. One exception is the gable-end truss in which webs run vertically. These trusses sit atop a building's end walls and are more like a wall than a truss. The gable-end truss must be supported along the entire length, and stabilized at the truss/wall intersection. There are a number of truss types that leave space for attic storage or living area. In any roof truss, however, attic or living space comes at a price. The bottom chord of the attac truss also acts as a floor joist and must be sized to accommodate a live load – typically between 20 and 50 psf. A roof truss with attic storage translates to roughly twice the weight of the same truss span with no attic. For example, a fifty-foot truss designed without attic storage may weigh between 300-350 lbs. A fifty foot truss designed with a 9 foot by 9 foot attic opening may weigh between 600 and 700 lbs.



Some truss manufacturers use a proprietary shape for the truss bottom and top chords. A non-proprietary shape truss is any truss made from standard cold-formed steel shapes, usually C-Shaped stud material. The standard and proprietary configurations have their advantages and disadvantages,

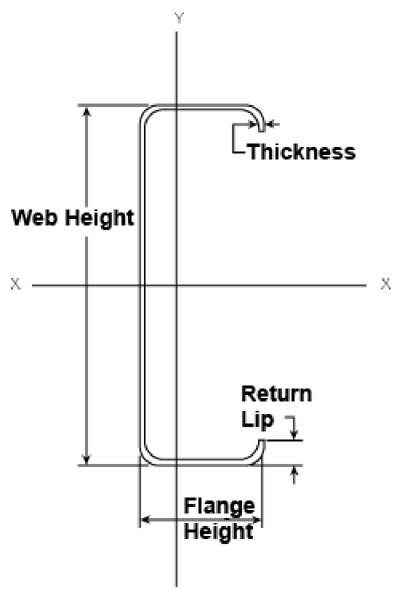


and it's up to the building designer to determine which is the best choice. Depending on the design, proprietary systems can sometimes utilize lighter sections for their chords and webs to satisfy the load requirements. This weight advantage can translate into cost savings. On the other hand, the lighter sections may not be as rigid as a standard truss, and consequently more difficult to install. On-site repairs on damaged trusses can be more time-consuming since the proprietery shapes cannot be purchased from any source other than the manufacturer.

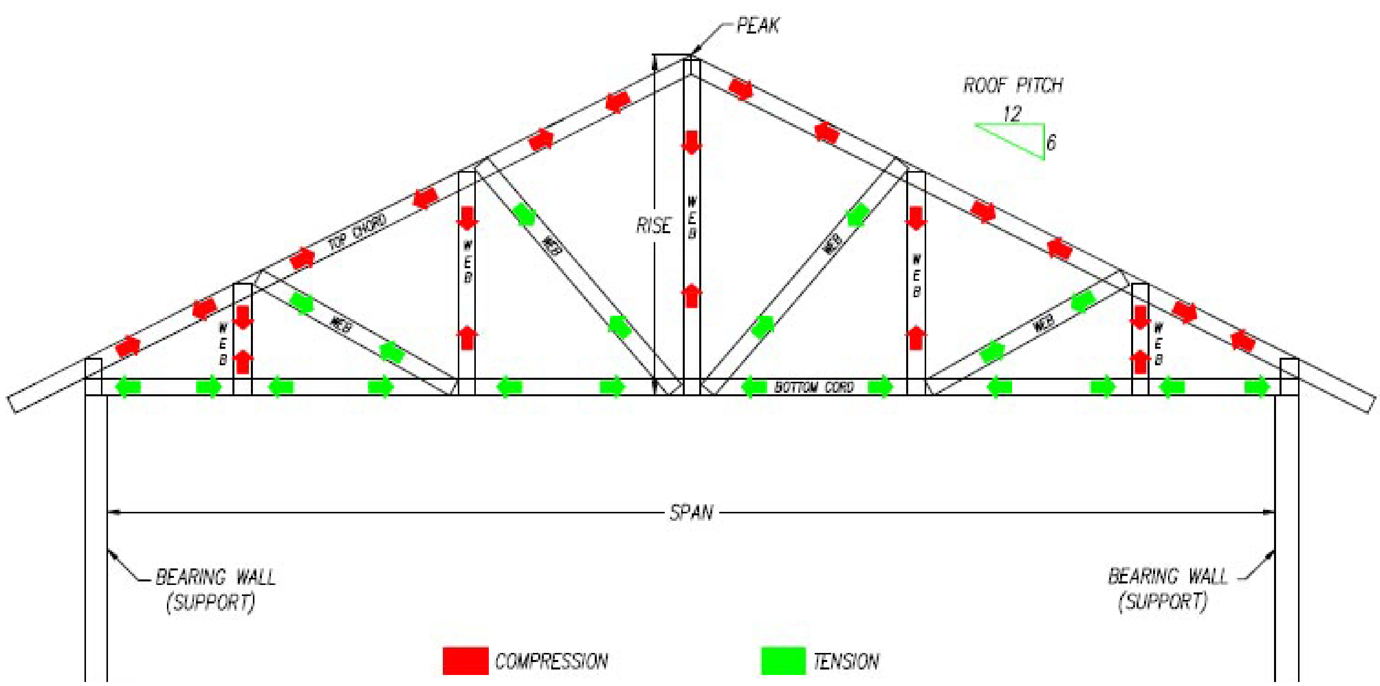
Roof truss strength derives from the triangle shapes that comprise the truss itself. Triangles are naturally rigid geometric shapes that resist distortion. Top chords are in compression and push out at the heel and down at the peak. The bottom chord is normally in tension to resist outward thrust. The webs form smaller triangles that strengthen the overall structure and provide rigidity. Loads on the individual webs can be either compression or tension - depending on the type of load.

Specifying a Truss

When specifying a roof system with a truss manufacturer, the builder/developer should include the span of the roof, the pitch, the top-chord overhang, the end cut and soffit-return details needed, and any gable-end preferences. Also needed are special loading requirements such as storage



Trusses are manufactured from C-Shaped Galvanized steel. The strength of each member derives from its geometry, rather than weight.



area or roof/attic mounted HVAC equipment. Typical stresses in a roof system show some members under compression and others under tension.

Inputs Required to Truss Manufacturer

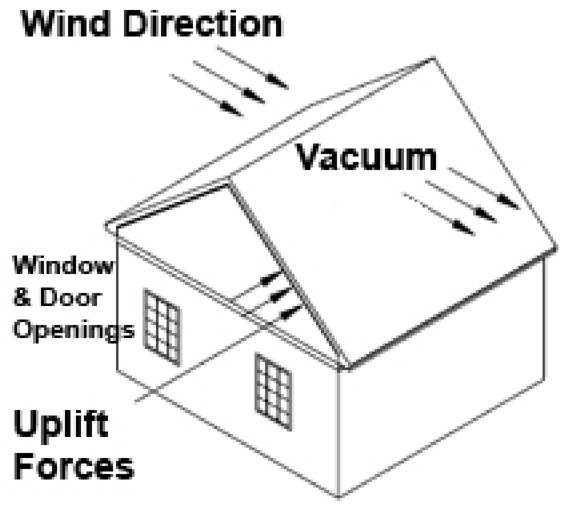
- Truss Type. Determines whether there will be storage or living space. Also defines architectural details such as soffit, overhang, fascia heights and tail length.
- Location. Determines the building codes and loads that apply. For example, in western California, seismic requirements may drive the design and cost of the truss. In coastal Florida, its wind that drives the design.
- Open Category.* Determines the proportion of openings (doors, windows, etc) to the overall wall area. Door and window openings can increase the pressure inside a structure during wind loading conditions.
- Wind Exposure Category*. Determines the amount of wind the structure will be susceptible to.
- Building Category. Determines the type of structure such as a hospital, school, residential, etc.
- Span(s). Determined by the building plans. If special requirements are needed, they need to be noted on the plans.
- Desired Roof Slope (Pitch). Pitch influences many of the design parameters and consequently has an impact on the overall truss weight.
- Building Plans. Building plans provide the truss designer/manufacturer valuable information on the wall types, thicknesses, spans, chord slopes, etc.

* Open Category and Wind Exposure are optional inputs. The truss manufacturor will determine these if not provided based on the building location and description.

Truss Design Process

Once the basic characteristics of a project have been communicated by the customer to the truss manufacturer, the design and manufacturing process proceeds fairly quickly. Nearly all major roof truss manufacturers use specialized computer software to assist in the truss design process. In the hands of a professional, these software applications can drastically reduce the time required to produce the optimal truss for a structure. An optimal truss is one that has been engineered to be structurally stable, as light as possible, and in compliance with building codes.

Aside from the location, type of building, and building code, which drives the building code, there are a number of parameters that feed the design process. As noted, the Open Category and Wind Exposure Category can play a significant role in the design and the required strengh of the truss system.



Door and window openings can increase the pressure inside a structure during wind loading conditions.

Under wind conditions, openings influence the pressure differential between the inside and outside of the structure. Under extreme wind conditions, the pressure inside the structure can be much greater than the outside pressure – putting uplift forces on the roof system. The pressure inside the building is greater when wind is allowed entry into the structure. Venting such as ridge and/or gable vents may help to relieve some of the pressure differential but are not considered by engineers to be a significant mitigating measure.

In 1992, Hurricane Andrew illustrated the importance of good roof design and sound installation practices. During that event, high winds peeled thousands of roofs from their structures and led to a major overhaul of building codes. In this event, nature drew upon the combined forces of inside pressure from openings, outside uplift pressures on the leeward side of the wind, and improper roof attachment. These factors led to the catestrophic damage and costly results.

To account for wind conditions in the local area, the truss designer will select a wind exposure category in accordance with local conditions.

The net result of all the input parameters into the truss design is an overall "Interaction Value" (IV) for each component of the truss. The IV is the ratio of required strength to available strength.

IV = Available Strength / Required Strength

For example, a truss designed for a storage building in the midwest US would have a significantly lower required strength than a hospital designed in the Gulf Coast (high winds) or West Coast (earthquake region). In short, location and building type drives the required strength. Required strength drives weight. Weight drives cost.

For most truss designers/manufacturers, the end result of a truss design is the shop drawings and computer generated reports that describe the characteristics of each truss.

Typical Truss Report parameters

- Design loads including dead load, live load, snow and wind loads
- Member sizes and strength characteristics
- Maximum design deflections
- Shop drawings with build instructions

Value Engineering in Roof Trusses

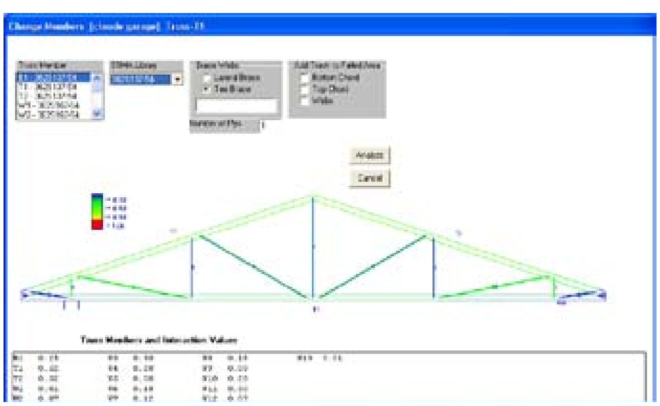
In today's economic climate, the term Value Engineering comes up in nearly any building design conversation. Value is the ratio of function to cost. Value can be increased by either improving the function or reducing the cost.

In the light gauge roof truss world, individual truss weight and total truss count is the usually the cost-driving factor. Consequently, value engineering for a truss is the process of engineering them to be as light as possible while meeting the building design and code requirements.

Truss design software can help tremendously in analyzing a individual truss and trimming unnecessary weight. However, much of the VE process falls into the hands of a truss engineer, armed with both automation and experience.

The VE process is iterative. The design engineer will typically perform a initial design using the lightest sizes and gauges that his/her intuition and experience allows. For example, on a thirty foot truss with no storage or living space, the engineer may select a twenty-gauge 3 5/8" bottom and top chord with 2 1/2" web members at a maximum of 4' spacing. From there, the engineer loads the parameters into a computer program, draws the truss, and performs a member by member analysis.

High-end truss design software, such as Truss D&E © (shown) is capable of performing a member by member pass/fail analysis. The result of the analysis is the so-called "Interaction Value" which is the ration of required to available strength.



Truss D&E© calculates the "interaction value" on a section by section basis. Items below 1.0 exceed strength requirements. Items above 1.0 fail strength requirements. (for more info see www.jfba.com)

Once the initial pass fail-analysis is done, the design engineer will strengthen failing members, trim over-designed members and re-run the analysis. This process repeats until the truss is optimized.

Value Engineering Techniques (on a Single Truss)

- Increase or decrease gauge (thickness) of the member or section
- Increase or decrease size (web or flange) of the member or section
- Increase or decrease the panel width
- "Overcap" the top or bottom chord with light gauge track (strengthening technique only)
- Apply "T-Bracing" to failing webs with light gauge track (strengthening technique only).

T-Bracing for example, adds only minimal weight because it uses of geometry rather than size or weight to provide additional strength.

Cost Drivers

Value engineering occurs *after* a truss has been selected. There are a number of items that can drive cost before the truss design process begins.

- Attic space. In attics, the bottom chord plays a dual role of truss member and floor joist. Attic trusses will always increase the truss cost, sometimes dramatically, depending on the attic opening and bottom chord loads.
- Ceiling material. The type of ceiling material controls the allowable deflection in the truss design. If the finish ceiling material is brittle (such as plaster) the truss should be designed to resist deflection. Resisting deflection typical calls for larger or heavier truss, and added cost.
- Truss Slope. Taller trusses have more linear footage of material and usually more weight. They also transfer more lateral force to the walls of the building. This is because there is more surface area to catch wind and higher uplift loads on the leeward side. On low-sloped roofs, the roofing material choices can narrow. For example asphalt shingles should not be installed on roofs below 3" of rise for each foot of run (3/12)
- Truss Fascia Height. Typically, a taller fascia will strengthen the overall truss strength, and can lower the truss weight.
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- Sheathing Type. The roof sheathing type plays a major role in the quantity of trusses required. For example, a 3/4" plywood roof will generally require truss spacing below 32". Some metal decking can be installed on roof trusses spaced up to 48".

Manufacturing

Steel roof trusses are typically assembled on large metal or wood tables. The tables are fitted with pins and clamp fixtures that hold the truss pieces in place. Chords and webs are placed in the jig, and then drilled using #10 self-tapping hexagonal screws. After the jig has been completed, it typically takes two experienced workers a short time to lay out the material attach them with screws. Ideally, the truss is loaded directly on the delivery truck. However, when this is not possible, the completed trusses are stacked, banded and stored in the truss yard, either vertically or horizontally. When hauling steel trusses, they are stacked along their bottom chord and secured at the top with additional pieces of light gauge track or stud.

Step 1. Truss material comes off the assembly line cut to length and machine-labeled. The material for each truss is stacked and staged on movable carts and staged for assembly.

Step 2. Machine-labeled stock is placed in the jig

Step 3. Webs are screwed to the top and bottom chords.

Step 4. Trusses are loaded onto trucks directly from the assembly stations. This assembly station, located in Freeport, FL has a built in crane/boom assembly to place trusses directly onto waiting trucks.

Truss Installation

Like any roof truss, steel roof trusses are best installed by crane and an experienced crew. There are a number of industry best practices for installing trusses. The most critical are discussed below:

- Trusses should never be attached rigidly to interior partitions. This can induce bending forces that trusses aren't designed to carry. Rigidly attached trusses have also been known to lift an non-load-bearing interior wall from the floor.
- The truss installer should always follow any special instructions by the manufacturer. For example, T-Bracing - a common web strengthening technique - is best applied on the job site. Failure to install the bracing can

drastically alter the strength of the truss system.

- Most roofs, regardless of their location are designed with a fixed end and a slide end. This approach significantly reduces the amount of lateral force on the walls supporting the truss system. Strengthening walls against lateral forces – particularly at the top of the wall is difficult. Therefore, the approach is to reduce lateral force on walls by allowing the truss to slide horizontally. Several manufacturers make so-called "Slide connections" which allows the truss to move horizontally, while preventing any vertical movement.
- Trusses should never be modified or cut without first seeking engineering advice. If the truss was damaged during shipment, the installer should contact the truss engineer for a workable repair scheme.
- If possible, the crane should be positioned before the roofing materials and trusses are dropped at the site. This assures that materials won't need to be moved again after delivery. Before lifting trusses to the roof, the crane hoists the sheathing, and finish roofing to the top floor. While the roof materials go up, gable trusses should be sheathed and sided while still on the ground. This time saver eliminates the need to set up tall staging at the gable ends.