Roof Framing with Cold Formed Steel Trusses

By Michael Pellock, P.E.

What has been the fastest growing segment of Cold-Formed Steel (CFS) construction over the past decade? What segment of CFS construction has blossomed from rather humble beginnings in the early 1990's to an estimated $200 million market? What segment of CFS construction has spawned the development of new products and state-of–the-art CAD and design software? The answer is pre-fabricated roof trusses.

CFS construction has been a part of the building industry for decades. Typically, this involved conventional curtainwall or load bearing walls framed on the job site. When architectural roof lines were required, they were usually framed with conventional rafter construction or site-built trusses.

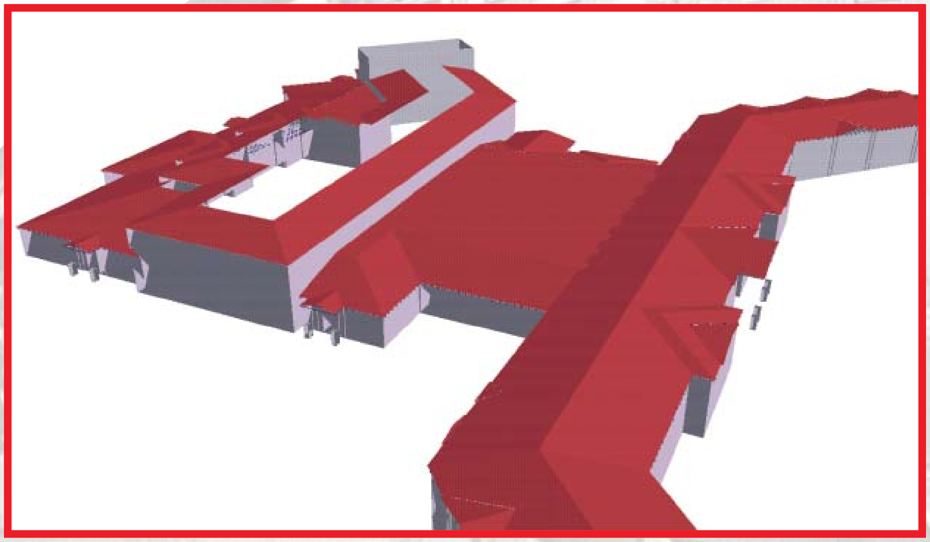
In the early 1990's, a new market was developing. With a history of success in the pre-fabricated, metal connector plated wood truss industry, several of the leading metal truss plate manufacturers began developing the CFS truss market. At that time, most trusses were supplied by drywall framers building C-stud type trusses on the job site. However, it did not take long for the new CFS truss entrepreneurs to realize that the C-stud truss did not lend itself well to high production truss fabrication and delivery. To address those challenges, unique CFS shapes were developed specifically for high volume truss fabrication. Software for roof layout and truss estimating and design was developed as well. By the turn of the new century there were truss fabricators supplying pre-fabricated CFS trusses in just about every corner of the United States.

Today, pre-fabricated CFS roof trusses have become the norm in applications ranging from simple mansard framing in strip malls to long spans over gymnasiums and church halls. CFS trusses are used in a wide scope of facilities and functions including schools, hotels, retail facilities, banks, fire stations, assisted living, correctional facilities, military housing, churches, stadiums, office buildings and residential homes.

The Design Process

Today's CFS truss fabricators designers are armed with software that gives them the ability to quickly and accurately layout and design the roof trusses needed to create the architectural design of the roof. From the architectural drawings, the truss fabricator will evaluate the most efficient method to create the profile of the roof. The flexibility in the software and truss products provide for an almost limitless array of roof and ceiling configurations.

In order to create the roof profile, many types of trusses may be incorporated. Common gable trusses span from one support to another. Girder trusses are used to support trusses or framing where other structural supports are not available. Valley trusses are placed above common trusses where intersecting roof sections create valleys. In the case where the truss height may exceed fabrication or shipping limits, the single truss may be truncated and replaced with a combination of "base" and "piggyback" trusses.



Once the layout of the trusses has been finalized, each truss is designed with the appropriate loads and load combinations. Truss members are designed following the design procedures for CFS members per the *American Iron and Steel Institute Cold-Formed Steel Design Manual, 1996 Edition* or the *North American Specification for the Design of Cold-Formed Steel Structural Members, 2001* and *AISI Standard for Cold-Formed Steel Framing – Truss Design, 2004*. It should be noted here that the snow, wind, live or seismic loads are to be specified by the project architect or engineer of record. Load combinations typically follow the recommendations of ASCE 7, unless specifically spelled out by the EOR or the governing jurisdiction. In order for the truss designer to proceed with the design of the trusses, two assumptions related to the work of the building designer must be made. First, that the supports are properly designed for the truss gravity and uplift reactions. Second, that consideration has been made to provide for bracing of the truss top chord and resistance to lateral loads perpendicular to the truss. In other words, a diaphragm is required.

In addition to the design of the individual trusses, the truss engineer will design the connections associated with the truss system. There are basically two categories of connections that are addressed by the truss engineer: Truss to truss connections, and when required by the EOR, truss to support connections. Truss to truss connections include the connection of truss to girder truss, valley truss to common truss, piggyback truss to the base truss when the connection of two truss overhangs over a corridor, etc. Truss to support connections address the connection of the truss to other elements of the building that provide support to the trusses. These include connection of the truss to concrete and CMU walls, structural steel, cold-formed steel framing, bar joists, etc. Truss to truss connections are easily specified by the truss designer. The loads involved in the truss to truss connections are based on the designs of the individual trusses involved in the connection. The truss designer knows these loads and understands how the connections are made.

When it comes to the design of the truss to support connections, the building designer may be required to provide some important information to the truss engineer. When designing this connection, the truss engineer knows the gravity and uplift reactions from the individual truss designs and can design the connection for these loads. However, when the building designer requires the structural support to be braced for out of plane forces, and the truss to support connection is an integral part of the support bracing, the building designer must specify that force. The out of plane forces referred to here could be from wind loads applied to a wall or buckling forces from a beam. The truss engineer can then incorporate that force in the design of the connections. These out of plane forces are ultimately resisted by the diaphragm via the truss to support connection and the truss to diaphragm connection. Truss to truss and truss to support connection designs may incorporate special proprietary products or typical off the shelf products, as well as a wide array of fasteners.

Fabrication

Most CFS truss sections in use today have been developed specifically for pre-fabrication in a high volume manufacturing facility. Their designs allow for more efficient manufacturing, stacking and delivery. The fabricator's software becomes a vital tool for expediting the fabrications process. From the software, the fabricator creates material cut lists for efficient cutting and staging. Table jig setup is established for the most efficient use of table space and setup. Fastener requirements are reported on easy to read shop drawings providing for quick, efficient and accurate truss assembly. Some fabricators utilize laser systems that project the image of the truss and screw requirements for each connection onto the fabrication table. This technology significantly reduces the time to setup each truss configuration, and also

eliminates errors that can occur when setup is done manually. To insure high quality, in-plant quality control programs are established detailing the types and frequency of checks that are to be made throughout the fabrication process. Third-party inspection and plant certification programs are available to the fabricator as well.

Installation

CFS trusses are delivered to the job site, ready to be installed. Typical installation involves the use of a crane to lift the trusses in place, where they are connected to the support and temporarily braced. Temporary bracing, often referred to as construction bracing, it essential for safe truss installation. Lateral and diagonal bracing is attached to the chords and webs to stabilize the trusses until the permanent bracing system is applied. The Light Gage Steel Engineers Association, LGSEA, has published a document, *Field Installation Guide for Cold-Formed Steel Roof Trusses*, that addresses proper installation of CFS trusses, including handling, installation bracing and tolerances. Proprietary products have been developed specifically to help expedite truss installation by providing a quick way to brace and properly space trusses at the same time. It is important to understand that the LGSEA document only provides recommendations for installation bracing. This document does not address permanent bracing procedures or requirements (see STRUCTURE magazine, April '04).

Design Responsibilities

The building designer or engineer, and the truss designer or engineer, must work in harmony to facilitate the truss design process. It is important that all parties agree where responsibilities lie. The Committee on Framing Standards, COFS, of the American Iron and Steel Institute has published general guidelines for design responsibilities as part of the *AISI Standard for Cold-Formed Steel Framing–Truss Design*. This standard states that the building designer's responsibilities include foundation design, structural member sizing, load transfer, bearing conditions and the structure's compliance with applicable codes. The building designer is also responsible for the specification of all design loads, the design of truss supports and anchorage, permanent truss bracing to resist wind, seismic and other lateral forces acting perpendicular to the plane of the truss and permanent lateral bracing as specified by the truss design. Check with the truss supplier, but design work such as anchorage (truss to support), permanent truss bracing and load transfer within the truss plenum (for example, transfer of diaphragm shear) may be provided by their truss engineer.

Limits

As an architect or building designer is evaluating a particular building for the possible application of CFS trusses, there are some guidelines to consider. Although each project and design condition is unique, there are some general limits that should not be exceeded without close consultation with a qualified CFS truss engineer:

- Clear spans greater than 80 feet
- Long span girders that support long trusses. (For example, diagonal girders through the corner of the building. This condition may need a structural steel truss girder.)

- Trusses with bottom chord slope that exceeds ½ of the top chord slope.
- Long span low slope trusses with low overall heights
- Long overhangs (greater than 5 feet)

Although these conditions can certainly be evaluated by the truss designer, keeping them in mind could avoid design complications.

Industry Organizations

A number of CFS organizations have been created over the past 12 years that generate and disseminate information related to CFS framing to the engineering community. These organizations are dedicated to developing procedures and standards to simplify the use and specification of CFS framing. They include The Light Gage Steel Engineers Association (LGSEA), the AISI Committee on Framing Standards (COFS), the Steel Framing Alliance (SFA), and the Steel Truss and Component Association (STCA.) These organizations are resources that the structural engineer can call on to get questions answered and are great resources for technical information. Check out their web sites for further information.

In Conclusion

The pre-fabricated CFS truss industry has been actively serving the construction markets for more than ten years, with great success. Pre-fabricated trusses have been supplied for the wide range of buildings in all areas of the country to resist wide ranges of live (snow) and wind loads. There has been no lack of imagination in the shape of roof profiles, configurations and functions that architects have expected of truss products. At the end of the day, pre-fabricated CFS trusses have been able to meet the architectural and structural challenges presented by ever changing demands of today's building market. Consistent structural performance, flexibility in design and cost effective fabrication and delivery make CFS trusses an excellent solution for roof systems.■

Michael Pellock, P.E. is Vice President of Technical Services for Aegis Metal Framing, LLC, located in Chesterfield, Missouri. Aegis supplies Ultra-Span® products, engineering services and software to CFS truss fabricators throughout North America and Europe.