Steep Roof Construction Using Engineered Wood Trusses

By Lyle D. Hogan and Richard Reynolds

ABSTRACT

Steep roof inclines may be created with site-fabricated "stick-built" elements of lumber or by engineered wood trusses manufactured in a factory-type setting. *Figure 1* depicts the former, a system of built-in-place framing as opposed to engineered trusses. Site-built roofs have a long history of application. Wood trusses, however, offer many advantages, including design that accounts for applied load conditions and tighter quality control. This makes them a product of choice for the majority of residential and light commercial roof applications.

Use of engineered wood roof trusses appears to be gaining both popularity and market share. Construction is no longer limited to residential structures. Large office complexes, churches, banks, agricultural storage facilities, and many other applications are now commonplace uses of the product. Conventional low-slope roofing projects may also include a portion reserved for wood truss construction.

The popularity stems, in part, from the impressively long spans that are available without the typical penalties of size and weight inherent with some other construction materials. In addition, wood is a readily available and fully renewable resource.

Long spans are afforded by the triangulation arrangements of the respective members constituting the truss. The long span construction reduces the need for column supports and yields wide flexibility in interior partitions. This triangulation also permits the individual pieces to remain compact.[1]

Following is an overview of wood truss construction features. Stick-built framing, with its similar bracing requirements, is used for contrast and comparison. Distinction is made among truss types, connection features are examined, and cautions are offered to avoid substandard performance.

Figure 1: Built-in-place (stick-built) framing.

Figure 2: Bundle of pitched gable and trusses. Having only vertical web elements, these are to be supported along the entire length of the end walls.

TRUSS CONFIGURATIONS AND TYPES

Many different pitched truss profiles may be encountered. The typical pitched truss is a dual-pitched symmetrical truss having a horizontal bottom chord (*Figure 2*). Having no triangulation web elements, the product shown is intended to be supported throughout its length by the wall and is therefore called a gable end truss.

The typical scissors truss also has a dual-pitched symmetrical profile, but with a bottom chord, usually sloping at half that of the top (*Figure 3*). There are many variations available from these fundamental shapes, apparently limited only by the designer's imagination and manufacturing capabilities.[2]

Certain truss arrangements may be so geometrically bulky that transportation problems become apparent (*Figure 4*). Separation lines, therefore, may be identified during design, and the modular shapes delivered in more convenient fashion. The components are then joined at the site of construction through a piggy-back (discussed below), pinned connection, or other type of union.

TRUSS PLATE CONNECTORS

The chords and webs can be secured at joints by several different methods, including: bolts, split ring connnectors, shear plates, plywood gussets, and metal connector plates. Most wood trusses built today use the metal connector plate as shown in *Figure 5*. These are sometimes referred to as "gang nails," but that is misuse of a proprietary name equivalent to "drinking from a Styrofoam® cup" or "making a Xerox® copy." Gang Nail Systems, Inc. (purchased by MiTek Industries in 1987) was one of the original vendors who began marketing metal connector plates in the 1950s. While the metal connector plates from various manufacturers may look similar, design values differ and are proprietary. Evaluating the great variation in the shapes, materials, and properties of connector plates is the interest of The Truss Plate Institute.[3]

Considering their relatively small size, the load-carrying capability of truss plates is remarkable. When pressed into position on a splicing table or jig (*Figure 6*), the metal connector plates have demonstrated commendable performance for over 40 years. It is noteworthy that rough handling of trusses may induce loosening of the connection. Back-out (of the truss plates) by only 1/16" may diminish load-carrying capability to only 60% of the design performance value.[4]

TRUSS UPLIFT

Roof construction technologists may be surprised to learn that truss uplift has nothing to do with wind uplift forces and resultant loss so commonly encountered. Also known as rising trusses, truss arching, and partition separation, this phenomenon is characterized by the apparent separation of the ceiling from the wall (evident as gaps opening in the winter and closing in the summer in some structures).

The extent of the parting line may be seasonally influenced by the humidity present in the attic. The lower chord of a truss is kept fairly warm, commonly enveloped entirely by the attic insulation.[5] This chord tends to shorten with ongoing drying afforded by the warm setting.

On the other hand, the humid attic air present during some seasons can surround the upper chords and result in the lengthening of those members, subjecting them to upward bowing. Owners may be entirely convinced that the structure is settling. In fact, the

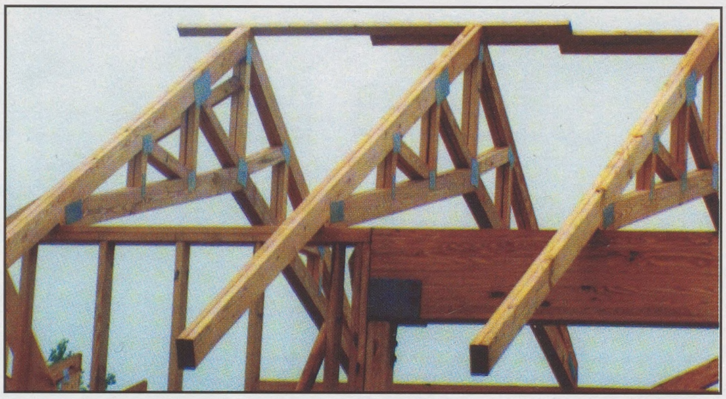

Figure 3: Ordinary scissors truss. Slope of lower chord is usually half that of the upper chord.

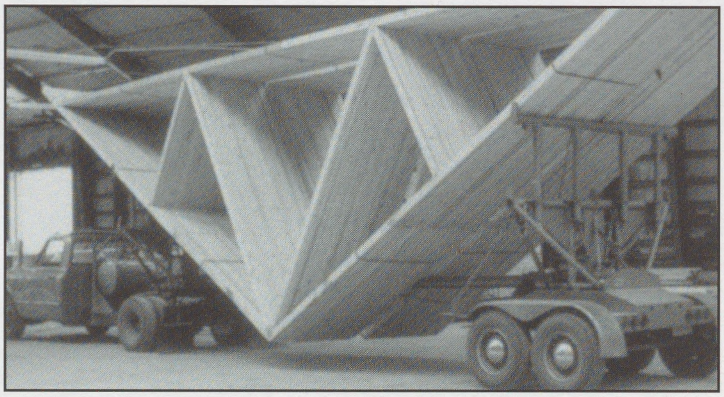

Figure 4: Truss sizes vary considerably. The means of transportation varies accordingly. Photo courtesy of Wood Truss Council of America, Madison, WI, (608)-274-4849.

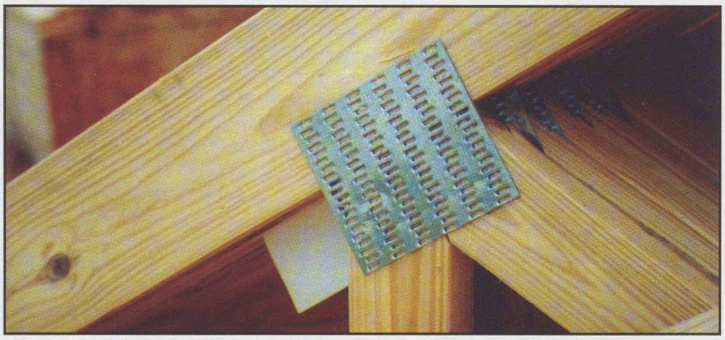

Figure 5: Truss metal connector plate.

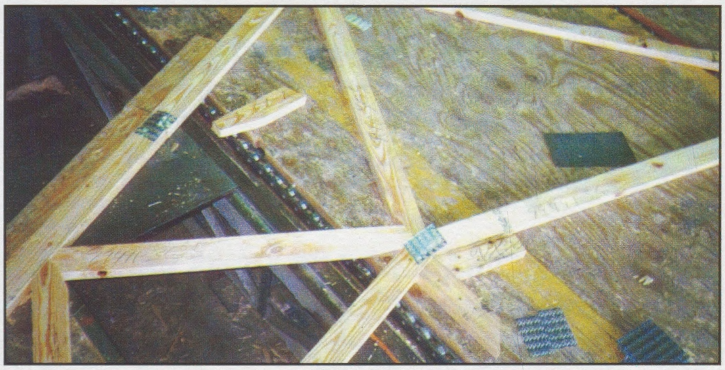

Figure 6: Metal plate-connected wood truss being assembled on the truss manufacturing table (jig). Photo courtesy of Blue Ox Industries, Inc., Kernersville, NC, (800)-672-2145.

Figure 7: A "piggy-back" will be added to these trusses to continue the uniform slope to the ridge line. Such construction may be implemented where transporting difficulties arise from geometrically bulky trusses.

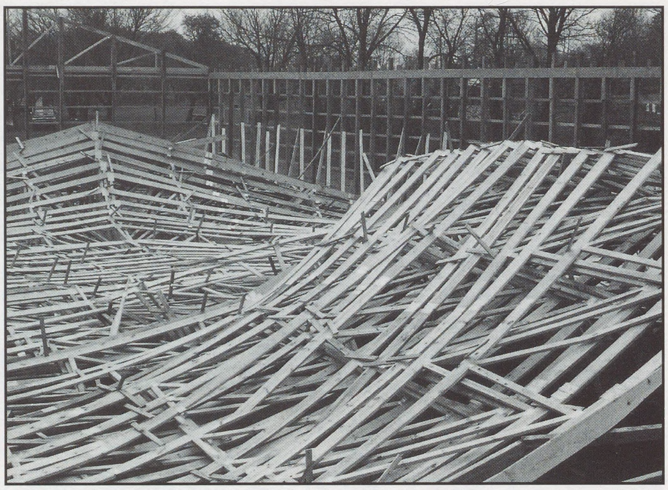

Figure 8: Use of "killer cleats" as installation bracing can lead to truss collapse such as this. Photo courtesy of Wood Truss Council of America.

lower chord of the truss is rising in relation to the top plate of the wall.

The juvenile wood (inner growth) now prevalent in construction has a greater tendency to behave in this manner, being more hygroscopic. The more mature wood formerly used was more dimensionally stable. Unfortunately, present tree farming practice is to harvest this younger growth to satisfy market demand. Occasionally, attic ventilation improvements alone can curtail the behavior to a tolerable level. Our experience has shown ventilation to be inadequate in many instances of steep roofing.

THE PIGGY-BACK ARRANGEMENT

When a particularly tall truss is specified, there may be shipping difficulty because of vertical clearance limitations encountered in transit. In response, the plant may configure a piggy-back arrangement where the uppermost reaches are added to the truss once it is in place (*Figure 7*). This arrangement is one of several site-specific conditions requiring good understanding of lines of responsibility for installation.

The importance of proper connection between and among these modular parts cannot be overstated. The requirements for this field assembly are provided by the truss designer on the drawings and must be followed by the installer to ensure proper performance. It is particularly important to properly brace the top chord of the "flat top" truss to prevent buckling.

BRACING (PERMANENT AND TEMPORARY)

As with any structural member, load-carrying capability is contingent upon the loads being applied in the plane anticipated by design. Rotation of the member out of that plane will certainly reduce performance (of these and any other element of support). Therefore, bracing is necessary to keep structural elements in their intended position.

Some bracing elements are temporary in nature, used only for initial alignment. An improper practice for temporary bracing is the use of short 1x or 2x lumber spacers. These members are called killer cleats. Some instances of temporary bracing observed by the writers have failed to inspire confidence (*Figure 8*). Moreover, it is not always understood that these temporary pieces, even closely spaced, do not substitute for permanent bracing. Study in the aftermath of wind destruction has occasionally revealed the omission of any lateral bracing (*Figure 9*).

Figure 9: Progressive failure of truss system from inadequate lateral bracing. Photo courtesy of RCI.

The deck (whether plywood, OSB, or tongue-and-groove planks), once installed, imparts considerable stiffness to an array of structural supports; however, required shear diaphragm resistance is not always developed by this cladding alone. As shown in *Figure 10*, critical elements of carpentry are necessary to gain the lateral load resistance necessary. The example shown is a built-in-place arrangement, but similar longitudinal bracing is necessary for engineered trusses (*Figure 11*). Note that these bracing elements must embody a prescribed arrangement,

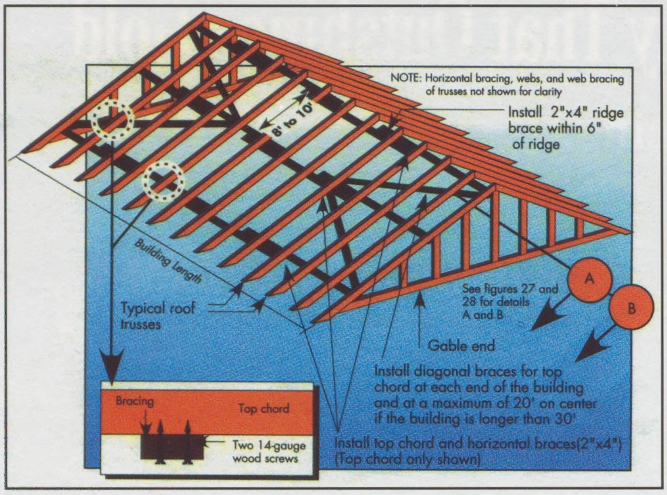

Figure 10: Lateral bracing for group of rafters. Photo reprinted courtesy of Federal Emergency Management Agency, (FEMA) Washington, DC.

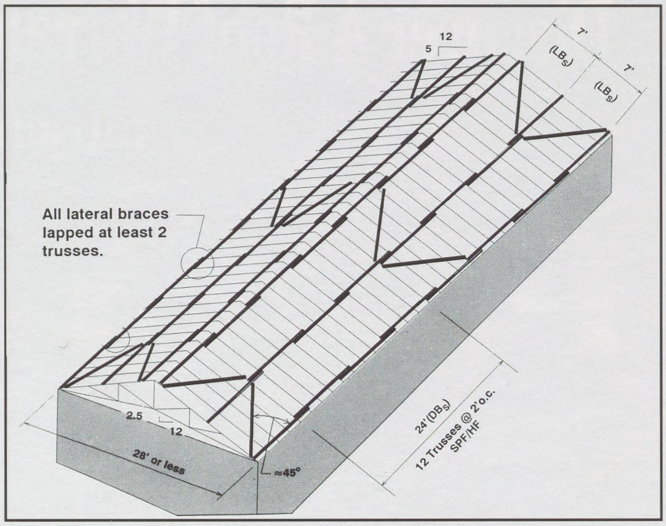

Figure 11: Permanent bracing for scissors truss. Photo courtesy of Wood Truss Council of America.

usually spanning at least three structural members. Additionally, there are requirements for lapping, usually by a minimum of two structural members. In addition to top chord bracing, trusses may also require permanent bracing in the web members as well as along the bottom chord (ceiling plane).

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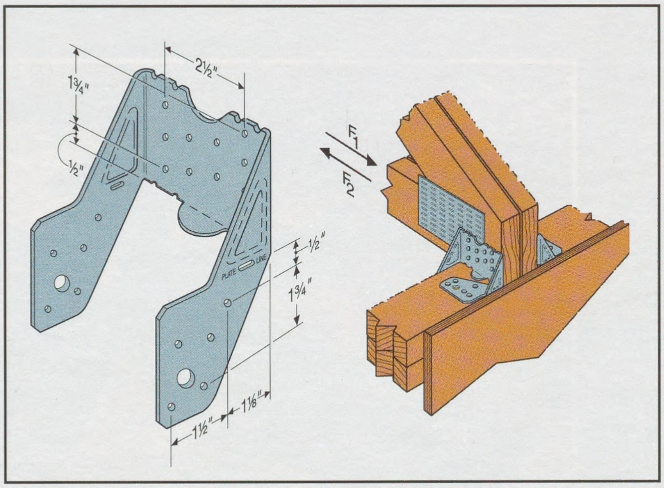

Figure 12: Proprietary truss bearing connnectors. Photo courtesy of Simpson Strong-Tie Co., Inc., Pleasanton, CA (800)-999-5099.

All such requirements of bracing should be stated on the design drawings from the truss manufacturer. Three features of interest must be communicated on the drawings:

- Lateral bracing perpendicular to the bottom chord. This is usually one full run for each 15 feet of width.
- Lateral bracing perpendicular to the top chord; also one full run for each 15 feet of width.
- Cross brace the webs 20 feet on center.

It is the continuity of the bracing that accomplishes the task. Prudent practice and high wind zone requirements dictate that the bracing be fastened with wood screws as opposed to sinker-type nails.[6]

DELIVERY, HANDLING, INSTALLATION

Trusses can be summarily ruined during transport and handling. Failure to lift from designated panel points together with reckless storage practices have been named in litigation as the origin of defective work. Multiple pick points, spreader bars (1/2 to 1/3 of the truss length), and strongbacks are available and recommended during crane

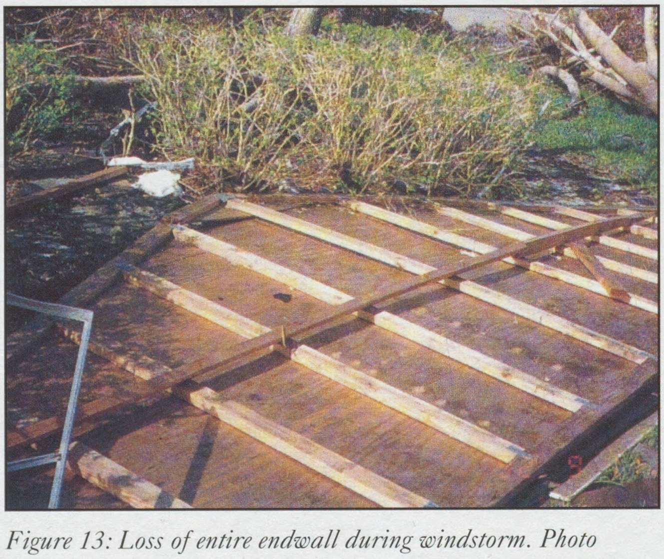

Figure 13: Loss of entire endwall during windstorm. Photo reprinted courtesy of FEMA, Washington, DC.

lifting, particularly for longer truss spans. Tag lines attached to the truss ends permit control while positioning.

The juncture of the roof-to-wall is well known as a weak link in steep roof construction. Loads resulting from high winds have sometimes cleanly separated the roof from the standing walls. This behavior is avoidable by most accounts. Arguably, some roof coverings may be destroyed, but the structure should remain in place in most instances. Destructive weather events of recent years have produced widespread damage, notably owing to this connection.

More effective, wind-resistant construction is readily attainable through the use of proprietary hold-down hardware available for roof-to-wall connections (*Figure 12*). These pre-punched and pre-shaped metal accessories are particularly handy for enhancing the union where the truss (or rafter) heel bears on the wall plate. The toe-nailed connection ordinarily configured at this union offers very little resistance and has frequently been shown wanting.

ENDWALL CONFIGURATION

Gabled roofs may warrant closer scrutiny than those closing with hips. As shown in *Figure 13*, loss at gable ends is a fairly common mode of wind damage, frequently traceable to the marginal (or absent) lateral bracing.

In contrast, hip ends have inherent lateral strength not present in gabled roofs. This, of course, does not negate the need for specified bracing in hip roof arrangements. This stronger natural shape results, in part, from the more streamlined ends, better spoiling the attacking winds when compared to vertical gables.

CONCLUSION

The practitioner of steep roof design may think to avoid liability by steering clear of jobsite inspections; or the task of learning installation techniques may appear too daunting. After all, won't the contractor or supplier know far more than the occasional observer? It is hoped that, armed with these few morsels of learning, the inspections may become more meaningful.

Engineered trusses provide a sound structure with more flexibility in design than conventional framing methods. Proper connections, handling, and bracing are crucial to successful performance.

ACKNOWLEDGEMENT

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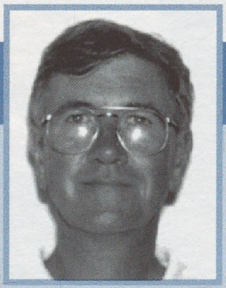

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