TRUSS-FRAMED CONSTRUCTION
The recommendations contained in this manual are based upon the collective experience of engineers and builders who are familiar with the Truss-Framed System. These suggestions do not cover all techniques of truss-framed construction. Nor do they prescribe the only acceptable or preferred standard or practice. The authors are solely responsible for the accuracy of the statements and interpretations contained in this publication and such interpretations do not necessarily reflect the views of the Government.

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TRUSS-FRAMED CONSTRUCTION

A MANUAL OF BASIC PRACTICE

Prepared by

NAHB Research Foundation, Inc.

in cooperation with

Forest Products Laboratory, Forest Service, U. S. Department of Agriculture
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Illustrations by Laurence W. Miller
PREFACE

The Truss-Framed System (TFS) described in this manual is an innovative wood-framed construction method developed by the Forest Products Laboratory for residential buildings. The unitized-frame system provides for rapid and storm-resistant construction. This manual covers the basic details of design, fabrication and erection of the TFS, with sufficient detail to allow the designer, builder, and code official to evaluate and utilize the system.

Information on specific matters regarding TFS construction can be obtained from Dr. Erwin L. Schaffer, P.E., State and Private Forestry, Forest Products Laboratory, P.O. Box 5130, Madison, WI 53705.

Application forms for a USDA nonexclusive license to use this patented technology are available from:

U.S. Department of Agriculture, S&E Administrative Services Division
Chief, Program Agreements and Patents Management Branch
6505 Belcrest Road
Room 524, Federal Building
Hyattsville, Maryland 20782
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CONSTRUCTION
Fabrication
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Placing
Aligning
Bracing

SUMMARY
INTRODUCTION

The Truss-Framed System (TFS) is a new light-frame wood construction concept that integrates customary construction components—roof trusses, floor trusses, and wall studs—into unitized frames. It offers a new alternative in prefabrication and field assembly methods without basic departures from established building practices. It represents an engineered building system adaptable to a wide variety of design requirements and construction procedures, as illustrated by this manual.

The TFS concept was developed by the Forest Products Laboratory, Forest Service, USDA in Madison, Wisconsin, in response to the need for an economical, high-quality, and disaster-resistant framing system. A public patent, No. 4,005,556 has been issued to Roger L. Tuomi on this system and it is available to anyone who wishes to make use of it. TFS evolved from field observations that framing failures commonly occurred at connections between floor, walls, and roof. It became apparent that increased continuity from the foundation to the roof would lead to greater structural integrity without increased material requirements. In the TFS, continuity between individual framing members is developed by connectors, such as metal truss plates or plywood gymnset plates, capable of transmitting bending moment, shear, and axial forces.

Advantages offered by the TFS include savings in both construction materials and time. The system establishes consistent 24-inch spacing between frames and prevents a possible mix of 16- and 24-inch spacing in floor, walls, and roof. Elimination of floor beams, interior columns, and headers leads to further lumber savings. Factory assembly of frames allows maximum utilization of short lengths and reduces waste or loss at the construction site. Rapid field assembly of prefabricated frames reduces open time and leads to earlier completion. Truss floor construction allows easy installation of utilities, and the floor cavity can be used as a heating or cooling air supply or return plenum.

Extensive experience building TFS houses in the U.S. and in foreign countries has demonstrated the adaptability of the system to varying design and construction requirements.

Builders' Evaluations

Many builders and designers have expressed interest in TFS construction. Reactions of the first builders who gained field experience with the system have varied with differences between their previous construction practices and successes in solving the initial truss-frame supply problem.

- David Skinner of EC-ON-ERGY Corporation in Tampa, Florida, reports significant cost savings over previous construction practices for his single-family detached and attached houses. He considers time, material, and supply cost savings. EC-ON-ERGY's construction team of four workmen can erect four locked-in houses in two working days.

- Bill Pilgrim of Douglasville Building Components, Inc., in Douglasville, Georgia, reports that they save about $2,000 on a 1,200-square-foot house. The company has put up four homes per day using a crew of 10. These cost savings are comparable to the $2,300 difference in rough framing bids of the initial TFS demonstration house near Madison, Wisconsin.*

- R. R. Patterson, Construction Manager for the Daniel Shelter Systems Division of the Fortis Corporation in King, North Carolina, estimates, after building a prototype truss-framed house, that if all areas of possible material savings were employed to their best advantage the material for a truss-framed house would cost $349 more than their conventional model. They also recorded an additional $520 in labor cost but added that "most of this additional cost is attributable to

---
the framing crew's unfamiliarity with the truss-frame and the problem of job-site conditions". The Fortis Corporation's study also notes that projects designed around only three truss-frame configurations to assure large production runs could yield fifteen or more different house designs.

Skinner initially fabricated his own frames, but now buys them from various truss manufacturers. Pilgrim fabricates frames in his own truss plant. Patterson's analysis is based on purchased frames.

Savings associated with truss-framed construction will depend upon the degree to which builders can adapt the TFS to their designs and construction procedures. Alternate sources of supply may have to be explored, most notably in the area of windows, to avoid custom fabrication. Factors to consider in planning for cost-effective use of TFS include:

- Locating a component designer and fabricator. Whereas initial truss-frame manufacturing cost may be higher because of a fabricator's unfamiliarity with the system and setup charges, such costs may be reduced for larger production runs.

- Planning an efficient truss transportation and handling system. Larger frames may require special truck-loading, transporting, and handling procedures.

- Training erection crews to achieve optimal labor times and attain the desired quality of workmanship.

Code Acceptances

Recommended TFS design and construction procedures are based on established building code requirements. TFS is a fully engineered system and technical backup data attesting to the validity of the analysis and design procedures are available. Where specific approval has been needed, builders have gained acceptance by local code officials. The U.S. Department of Housing and Urban Develop
The truss-framed building system allows full coordination of engineering and architectural design objectives. The basic design procedure is described in this section in terms of engineering design methodology, architectural design examples, and design variations.

**BASIC DESIGN**

A truss-frame consists of a roof truss and a floor truss joined by exterior wall studs. The wide variety of possible roof and floor truss designs and combinations is illustrated by figure 1. End walls may be truss-framed with field-assembled stud infill, prefabricated in conventional construction, or built on site. One builder of truss-framed houses has characterized the system in this way, "The Truss-Framed System uses smart engineering instead of excess material to give me superior construction at lower cost".

Many TFS designs will use 2x4 and 2x3 members, but special spans or spacing situations may call for larger members. In high-velocity-wind areas it may be necessary to use 2x6 studs in truss-frames because available grades of 2x4 stud materials may be overstressed at the typical two-foot truss-frame spacing. Similarly, heavy snow loading, seismic loading, or flood plain location may require heavier members and/or framing connections. The TFS can be used in advanced energy-conserving structures such as double-wall, box stud and envelope designs.

**DESIGN METHODOLOGY**

The Truss-Framed System consists of engineered building components capable of providing superior structural integrity. Frames for each application must be specifically designed. Structural design should follow recognized engineering methodology such as given by the Truss Plate Institute’s TPI-78 and PCT-80 design specifications.* Appropriate design loadings must be selected to suit the specific location and building usage. Loading conditions are the greater of either code requirements or actual design load.

The Truss Plate Institute design methods are commonly used by truss fabricators. For the Truss-Framed System, design of the roof truss and floor truss portions of the truss-frame should follow these methods and the wall stud portion be designed with conventional engineering procedures (Figure 2). The design solution provides data on required lumber sizes and grades. It also identifies metal truss plate requirements at joints, which may vary between the plates available from different manufacturers. As a result, the truss specifications prepared for any given type of plate are not applicable to assembly with other plates.

An example of structural design output using the TPI methods for a one-story truss frame with typical residential loading is shown in Figure 4. The example shows lumber sizes and grades that can be used for a truss frame of the given configuration on a 26-foot span. Sizes are not shown because they vary with truss details and plate properties. As the TFS offers considerable design flexibility, no single configuration or truss depth is specifically recommended. Member sizes and required lumber grades may change with any departure from this example. These factors must all be considered by the engineer in the structural design.

In the development of the TFS, member stresses and deflections were predicted by a sophisticated modeling technique known as the Purdue Plane Structures Analyzer (PPSA)†.

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*Truss Plate Institute, Inc. 1978. TPI-78. Design Specifications for Metal Plate Connected Wood Trusses, Recommended Design Practice, and 1980. PCT-80. Design specifications for Metal Plate Connected Parallel Chord Wood Trusses. 100 West Church Street, Frederick, MD 21701.

†Forest Products Laboratory, Purdue Plane Structures Analyzer, A computerized Wood Engineering System, USDA Forest Service Res. Paper FPL 168, 1972. Forest Products Laboratory, Box 5130, Madison, Wis. 53705. NOTE: The computer program is being revised to include recent changes in design recommendations.
Figure 1. Some optional truss-frame configurations. The upper end of each stud is a member of its roof truss. The lower end of each stud extends to the lower edge of all wood floor trusses or joists.
Laboratory tests of full size truss frames show good agreement with deflections predicted by this computer method, which analyzes the complete truss frame as a unit without separating into components (Figure 3). PPSA, however, requires predetermination of member properties and other decisions on structural performance modeling; it may therefore, be of only limited interest to most designers and of limited application to typical design tasks.

As the TPI design methods disregard structural continuity between the roof and floor truss portions, questions have arisen regarding the effect of neglecting this continuity. To address this concern, the truss frame shown in Figure 4 was analyzed by the PPSA method using two different assumptions: (a) separate floor and roof trusses, and (b) complete frame. Calculated stresses varied by less than 5% between the TPI method and the two PPSA analyses. Larger studs (such as 2x6) can have a greater effect on stress distribution in trusses, but these considerations must be resolved by design engineers on the basis of builders' specifications.

Figure 2. Truss-frame breakdown for TPI analysis.

Figure 3. Truss-frame analysis by PPSA method.
Figure 4. Typical loading and lumber data for one truss-frame.
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![Figure 2. Truss-frame breakdown for TPI analysis](image)

![Figure 3. Truss-frame analysis by PPSA method.](image)
**ROOF TRUSS**

<table>
<thead>
<tr>
<th>CHORDS</th>
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<th>DESIGN CRITERIA</th>
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<tr>
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<td>2X4</td>
<td>NO. 2</td>
<td>D. FIR-LARCH</td>
<td>TOP CH. LL = 30 PSF</td>
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<td>7-1</td>
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<td>TOTAL LOAD = 55 PSF</td>
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<td>SPACING = 24 IN. O.C.</td>
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<td>D. FIR-LARCH</td>
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Figure 4. Typical loading and lumber data for one truss-frame.
**Single-Family Home Design Examples**

To demonstrate the feasibility of TFS applications in various localities, preliminary structural designs for three example houses were analyzed.* These houses were located in different regions and design conditions were determined by local code requirements. Performance requirements were easily resolved using lumber species and grades likely to be available to local truss fabricators. Details of these preliminary designs are not included because the responsibility lies with each designer for (a) dimensioning the trusses, (b) selecting proper lumber species, grades and sizes, and (c) specifying the connectors to carry the design loads required by local code.

*Illustrated in U.S. Forest Products Laboratory. Truss Framed Systems. Forest Products Laboratory, Forest Service, USDA, P.O. Box 5130, Madison, WI 53705.

**Astoria** (Ranch). The Astoria house (Figure 5) was adapted to the market and local codes of the city of Astoria, Oregon. The original TFS demonstration house in Arlington, Wisconsin is similar to this design.

The ranch house can be built with full truss-frames over basement or with partial truss-frames on a concrete slab. The garage with its ridge running in the direction shown is most easily framed by conventional methods, but may be constructed with partial truss-frames by turning the ridge through 90 degrees.

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*Figure 5a. Truss-frame for Astoria model.*
Figure 5b. Astoria Design
**Bowling Green (Split-foyer Bilevel).** This bilevel or raised ranch model (Figure 6) was designed for Bowling Green, Kentucky. Its eight-foot-wide split-foyer entry is framed with three interrupted truss-frames, designed with truncated floor trusses. The lower level end wall garage door opening does not require a structural header if the end wall above is constructed as a truss-frame with conventional stud fill-in.

Figure 6a. Truss-frame for Bowling Green model.
Figure 6b. Bowling Green Design.
**New Bedford (Two Story).** This traditional New England model (Figure 7) was designed to meet the code of New Bedford, Massachusetts. The two floor trusses are combined into a single truss frame. Second floor studs and roof form a partial truss frame. New Bedford loading requirements indicated 2x6 studs for the first story. Both first and second stories were designed with 2x6 studs to meet first story loading conditions and to provide for R-19 batt insulation in the walls of both stories.

![Figure 7a. Truss-frame for New Bedford model.](image-url)
Figure 7b. New Bedford Design.
Multi-Family and Commercial Buildings

The Truss-Framed System is also readily adaptable to multi-family residential and light commercial buildings. It offers clear spans that permit flexible floor plans. The floor trusses have adequate depth to accommodate wiring, plumbing, ducting or heating/cooling plenums. The structural integrity of the TFS is especially valuable to light commercial structures.

Non-Rectangular Buildings

The truss-framed system is highly versatile in conforming to non-rectangular designs. Composite "L", "T", "U" and "H" building shapes are configured as readily as with conventional trusses. Non-rectangular truss-framed residences are shown in Figures 8 and 9.

If an interior load bearing partition is not desired beneath the roof intersection, a beam or an engineered girder truss can be used to support the roof trusses in the area of cut-away studs. Framing of the roof surface at the point of intersection can be completed by conventional construction methods.

Size Considerations

The TFS concept is not subject to any prescribed size limitations. On the other hand, individual truss configurations, manufacturing facilities, or transportation routes may effectively limit the maximum size of truss-frames.

Transportation clearances may restrict the design of larger truss-frames while smaller houses may not require any further consideration. For example, a truss-frame with the following characteristics is under 14 feet in height:

- 26-foot span
- 3 in 12 roof pitch
- 12-inch heel joint clearance for insulation
- 7'6" finished ceiling height (a conventional rough opening height is 8'1-1/8").

This truss can be loaded flat for transportation on 14-foot maximum-width roads.

Where size limitations are encountered, options include:

- Using alternate truss designs to improve structural efficiency.
- Using upgraded lumber species and grades to achieve increased spans.
- Increasing lumber dimensions to improve structural characteristics.
• Decreasing ceiling heights to improve road clearances, to improve energy conservation, and to permit use of lower-grade studs.

• Using reduced roof slopes to avoid road clearance problems.

• Fabricating truss-frames as sub-assemblies when they exceed the dimensions of manufacturing facilities and then assembling them either at the factory or on site.

• Using lower-profile hip truss-frames. If a traditional peaked roof appearance is desired, triangular roof-peak elements can be added on site (Figure 1).

VARIATIONS FROM BASIC TRUSSFRAME

Some of the suggested design options require variations from the basic one-story truss-frame configuration. Such adaptations include combinations of full and partial truss-frames and use of conventional framing techniques along with truss-framed components.

Partial Truss-Frames

The TFS lends itself to production of separate truss-frame elements and assembly of such elements in the field. Partial truss-frames can be manufactured with one or more elements missing (Figure 10). This may be done for several reasons:

• Floor trusses may be omitted for building on concrete floor slabs or conventionally built decks.

• Any element may be site installed to facilitate handling and transportation. As previously noted, site assembly must be supervised or stipulated by the truss manufacturer.

• Multistory truss-framed buildings may be framed using partial truss frames in the upper stories (Figure 10). This method is described under Stacked Truss-frames.

• Conventional lumber or manufactured floor joists or off-center spliced joists* may be mated with partial truss frames where clearspan floor construction is not desired.

Split Truss-Frames

Truss-frames can also be factory-built in sections and assembled on site with truss fabricator assistance, (Figure 10). These split truss-frames may simplify transporting and handling tasks for wide-span or high-slope truss-frames. On-site assembly normally requires a portable hydraulic press unit to embed the toothed connector plates in position. Such presses can sometimes be site-furnished on loan from the truss manufacturer. When properly designed, nailed metal plates or glue-nailed plywood plates are also structurally acceptable for on-site assembly.

The field assembly crew must be trained in assembly procedures to avoid incorrect location of truss plates or handling stresses that could endanger the integrity of plate connections. Aligning fixtures should be used to assure precise alignment of elements being assembled.

Stacked Truss Frames

Multistory truss frames are restricted in size by transportation and handling limitations. They are, therefore, manufactured in sections and stacked during the erection process. It is quite possible to site-assemble multistory truss-frames. However, practical considerations favor an assembly technique similar to conventional multistory platform framing. This starts with a full truss-frame composed of a ground-floor truss, studs, and a second-floor truss. After erection of the truss-frames and sheathing of the floors, the upper story is framed with partial truss-frames consisting of wall studs and roof trusses as shown in the multistory illustration of Figure 10. Stacking

Figure 10. Partial truss-frames.
multistory truss-frames simplifies transportation, facilitates erection and provides the desired structural integrity. Some precautions should be observed: the stacked truss-frame studs must be aligned vertically and the partial truss-frame must be securely connected through the sole plate to underlying structures by nailing plates, straps, or structural sheathing or siding.

**Integration With Conventional Framing**

Some irregular framing conditions are more easily resolved by conventional construction in the field rather than by prefabrication. One such condition is the intersection of roofs in non-rectangular buildings, as mentioned previously. Another condition is illustrated by entry-floor-level adaptations.

The basic truss-frame often incorporates a 20-inch-high floor truss. This raises the floor level about 10 inches higher than would conventional lumber floor joists. This elevation is sometimes reduced by excavating soil under the crawl space and dropping truss-frame support onto a ledge lower than the foundation top. Cast-in-place concrete ledges or header concrete blocks may be used for this purpose. Clearance between soil and untreated lumber must meet local code requirements for protection of the wood members. Figures 11(a) and 11(b) show some methods of stepping up to floor level, using exterior or interior steps:

- Entry A, a conventional stoop.
- Entry B, a deck that provides an architectural feature as well as a raised entry.
- Entry C, a platform entry.
- Entry D, a shed extension of the truss-framed roof to provide a ground level doorway and interior steps. This can also serve as an air lock entry.
- Entry E, an entry in a non-TFS section of the house, in this case the garage structure. It has a ground level doorway and interior steps.
- Entry F, a split foyer.

A. Conventional stoop.

B. Deck entry.

*Figure 11 (a). Entry Variations.*
Entries D and E treat the floor elevation as an advantage by featuring "raised" living rooms.

D. Shed extension entry.

E. Garage-level entry.

C. Platform.

F. Split foyer.

Figure 11(b). Entry Variations.
This section covers construction details to be considered in the design of truss-framed buildings. Organized in three subsections it discusses basic framing, discontinuities and openings, and integration of subsystems.

**BASIC FRAMING**

Although the TFS construction method is considerably different from conventional construction, the completed building frame is very similar to a stick-built structure.

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**Figure 12. Basic building shell construction.**
The Building Envelope

The shell of the TFS building is similar to conventional in-line construction for 24-inch spacing of framing members. The most notable departure from conventional framing as shown by Figures 12 and 13, is the absence of top and bottom plates, which have been replaced by multipurpose spacer blocks. A number of options are available for the type and use of spacer blocks. They may be applied with clip angles or nailed in place (Figure 12). The spacer block at the floor line may be built up as shown; or two separate spacers may be used – one for drywall backup and firestop in the wall and the other as floor edge support between trusses.

Permanent Bracing

The structural designer must designate location, size, and attachments for all permanent bracing required in the truss-framed structure.* Truss-frames are plane structural components, and their design analyses assume that every truss member will remain in its assigned position under load. Permanent bracing must provide adequate support to hold every truss member in its design position, and to resist lateral forces due to wind or seismic loads.

Racking Panels

Truss-framed walls require code-approved bracing as do conventional stud walls, with the following further qualification:

*See Truss Plate Institute, Inc. 1976. Bracing Wood Trusses: Commentary and Recommendations. BWT-76. 100 W. Church Street, Frederick, MD 21710.
Figure 14. Single wall siding can be nailed directly to studs and sill.

Figure 15. If sheathing panels are not full wall height, backup edge blocking is required at the joint by some codes.

Figure 16. Flat metal X-bracing is acceptable under some codes but structural sheathing provides stronger and stiffer racking panels.
Roof Sheathing

Any code-approved roof sheathing is adaptable to the TFS. Nailing patterns should be carefully followed as with any other roof structural system. C-D INT plywood is recommended over 24-inch o.c. roof trusses. The left-hand number of the Identification Index in the grade-trademark must be equal to, or higher than, the truss-frame o.c. spacing, for example 24/0, 32/16, etc. Plywood is assumed to be applied continuously across two or more spans and applied face grain across truss-frames. Interior grade plywood with exterior glue should be specified for best durability. Exterior grade plywood should be used for the underside of the roof deck exposed to the weather and for closed soffits. Diagonal board sheathing, straight board sheathing, spaced boards, or other materials are also acceptable under many codes.

Floor Sheathing

Truss-framing can utilize any floor sheathing that is code-approved for the truss-frame spacing. The American Plywood Association’s Glued Floor System* is widely used for either single-floor or two-layer-floor constructions. Details of sheathing edge support along the outside walls are shown in Figures 12 and 13, and an installation is shown in Figure 17.

Interior Partition

Interior partitions for the TFS are identical to those installed in conventional wood framed houses with one exception. Because there are no top or sole plates in TFS exterior walls, the tie-in to the exterior wall may vary. One cost-effective method is illustrated in Figure 18.

Figure 17. Floor sheathing installation. (Forest Products Laboratory)

*See APA Glued Floor System. U405, American Plywood Association, 1119 A Street, Tacoma, WA 98401.
Roof Overhangs and Soffits

Roof overhangs used as passive solar design elements, weather protection features, or aesthetic expressions are as readily incorporated into the TFS as into conventional roof designs. Customary roof overhang and soffit details are fully adaptable to TFS construction. Figure 19 shows three popular soffit designs. Occasionally, ledgers or nailer blocks may be required to support the soffit returns. Gable overhangs can be framed with conventional ladder panels.

Cantilevered and Raised Trusses

A truss is cantilevered when both top and bottom chords extend beyond the point of truss support. Roof trusses are frequently cantilevered to "raise" the upper chord so an adequate thickness of insulation can be installed above the wall top plate. They are also cantilevered for aesthetic effect in designs such as mansard roofs. Floor trusses are cantilevered to provide overhanging floors as shown in Figure 20. Examples of raised roof trusses are shown in Figure 1.

Truss-frames can be designed for cantilevering. Like conventional trusses, cantilevered truss-frames require careful structural design to minimize structural weaknesses and dimensional changes associated with variations in service conditions.

Most raised or "energy" truss designs require that an additional web member be brought down to the bottom chord. This web carries compressive forces from the top chord, and it is imperative that the designer determine if it will require lateral bracing.

If cantilevered trusses are shipped as partial truss-frames with studs to be fastened on site, the bearing locations should be conspicuously tagged to avoid any possibility of reversal or displacement of bearing points.
Interrupted Members

The basic TFS concept of identical truss-frames standing in succession to form the sturdy framework of a structure seldom occurs in real life. Intermittencies in the symmetry of the structure are often necessary for doors, windows, stairways and fireplaces. These interruptions can be accommodated by the truss-framed system quite as readily as by conventional stick-built systems.

Wall openings may be conventionally rough framed and roof framing at such discontinuities can be filled out with conventional trusses. Some builders prefer to erect the building shell of identical truss frames and then cut studs for oversized wall openings. In either case, the rough framing of openings follows the same code-accepted structural details as in conventional stud construction.

If floor or roof trusses are modified, the discontinuity must be structurally designed. Examples include provisions for stairwells and large through-the-roof chimneys. It should be noted that truss-frames having truncated trusses will probably require temporary bracing to facilitate handling and erecting.

Door and Window Framing

The general rules for layout of openings in truss-framed houses are similar to those in conventional 24-inch o.c. framing:

- Locate wide door and window openings in the gable end walls, as in Figure 21, if possible. Gable ends are non-loadbearing and require only non-structural framing as shown in Figure 22.

- Maintain window horizontal dimensions in truss-framed walls at between-the-studs (nominal 22 ½-inch) width, as shown in Figure 23, where feasible. The 22½-inch windows are often installed in a side-by-side series to form a picture window. Windows may also be surface-mounted outside the studs, as shown in Figure 24.

DISCONTINUITIES AND OPENINGS

The typical 24-inch spacing of truss-frames cannot accommodate all needed or desired design options. Wider spacing is needed for stairs and doorways and, sometimes, for windows. Larger wall openings can be more easily accommodated in end walls, and stairways may be positioned outside the truss-framed portion of the structure. Where discontinuities in truss-frames are necessary, their effects on structural integrity can be minimized by proper design.
• Locate wider-than-22½-inch windows and doors next to a stud wherever practical. Rough-framing details for these wider windows and doors in truss-framed houses can be identical to details in conventional wood framing such as those shown in Figures 26 and 27. Rough framing can be either prefabricated or site-built. Any interrupted truss-frame members should be tied in to the rough framing with metal framing anchors, as shown in Figure 26, to avoid building in a "weak link"; if the members are tied in with structural-grade sheathing (such as plywood or fiberboard structural or nail-base) or siding, the anchors are not necessary.

• Install a sidelight adjacent to an insulated hinged door in lieu of a sliding glass door, for structural and energy efficiency.

It should be noted that if 22½-inch windows are installed between the studs of truss-frames, load-bearing lintels or headers are not required. The head and sill of the rough window opening can each be formed by a single flat 2x4 identical to firestop and spacer blocks, as shown in Figure 25.

Figure 21. Windows in non-bearing gable end wall (EC-ON-ERGY Corp.)

Figure 22. Framing for openings in end walls.

Figure 23. Between-the-studs window installation.
Figure 24. A surface-mounted, between-the-studs emergency egress window. (Wausau Metals Corporation.)
The insulated plywood box header in an energy conserving design.

Figure 25. Preparations for doors and windows in side walls (Forest Products Laboratory)

Figure 26. Conventional header in a truss-framed wall.

Figure 27. Insulated plywood box header for oversized windows or doors.

Emergency Egress
Truss-Framed System "Engineered 24" (formerly "MOD 24") or other 24-inch-o.c. layouts must conform with required emergency egress provisions. Any between-the-studs window designated as an emergency egress (most frequently a bedroom window) must be selected
and specified to meet applicable code requirements. Factors to consider in emergency window egress include:

- Determining rooms that require window egress under applicable codes.
- Designating any specific egress windows.
- Selecting between-the-studs windows meeting your code’s clear-opening requirements. The sliding hinges of some casement window models reduce the clear opening width in open position, clear-throw hinges may be required to maintain the required egress width. Single-hung or double-hung windows may have adequate width but insufficient height of clear opening to meet code requirements.
- Using surface-mounted egress windows, as shown in Figure 24.
- Cutting studs and installing wider-than-stud-space windows if necessary.

Stairwell Framing

Stairways may be oriented either parallel or perpendicular to the direction of the floor joists. Parallel orientation, as shown in Figure 28, requires fewer interruptions in the truss-frame layout.

In layouts requiring wider floor openings, it may be more practical to support the floor truss header on posts. Where such supports are not desired, the clear-span floor trusses along the opening (or trimmer trusses) can be designed for the increased loading. Another common alternative is the use of double trusses along the opening; in TFS, one such member would be a full truss frame, and the other a separate floor truss. In either case, the structural adequacy of such trusses is assured by engineering analysis for the required opening.

WARNING: TRUSS-FRAME MEMBERS MUST NOT BE SITE-CUT IN ANY MANNER EXCEPT AS SPECIFIED BY THE DESIGNER.

In conventional construction, stairway openings are framed with trimmer joists. In trussed-floor construction, such trimmer joists can be used but do not perform as structural members.
Fireplace Framing

Prefabricated fireplaces can be installed without major structural interruptions. A zero-clearance fireplace fully projected into the room, as shown in Figure 29, or in a corner location will require no truss-frame cutting. A flush or chase location requires cutting one or more studs. Factory-built triple-wall decorative chimney packages permit ceiling and roof penetrations between truss-frames, and a chase installation can avoid such penetrations altogether.

Masonry fireplaces should be installed in end walls. Fireplace designs that require truss interruptions should be avoided, but if they are used, the truss frames must be engineered and manufactured for the specific application.

INTEGRATION OF SUBSYSTEMS

All considerations in integration of subsystems in conventional construction remain equally applicable to truss-frame construction. Such considerations include anchoring of the wood frame to foundations, fire safety, thermal performance, and mechanical equipment installations.

Foundations

The Truss-Framed System is highly adaptable to different foundation types. Any substructure that allows effective anchoring of sill plates or other secure tie-downs for the truss-frame may be used. The structural integrity of the foundation and its anchoring system must equal that of the truss-frames to avoid building a weak link into an otherwise efficiently engineered structure.

Foundation systems that can be used with the TFS include:

- Concrete or masonry walls
- All-weather wood foundations
- Post, pile, pole, pier, or concrete frame structures
- Concrete slab-on-grade.

CAUTION: IT IS ESSENTIAL THAT EVERY STEP OF FOUNDATION CONSTRUCTION FROM LAYOUT TO FINAL SILL INSTALLATION BE PRECISELY MEASURED TO ENSURE THAT THE FOUNDATION IS SQUARELY AND ACCURATELY BUILT.
Elevated Foundations

The TFS offers unusual advantages in house construction on concrete frame or wood pole foundations in hurricane zones and sloping sites. The TFS allows the assembly of all rough framing in one simple step. Access from grade level to the floor line on such sites may be difficult. A truss-framed house on a concrete subframe is shown in Figure 30. The subframe, also could have been built in wood pole construction as in Figure 31. Such construction requires consideration of a few further factors.

Truss-frames must be anchored to their supporting beams with designer-specified connectors. Truss-frames are commonly assembled with hot dipped galvanized truss plates. For damp salt-air environments, metal connectors may require added protection from corrosion. Exposed truss plates in ocean-front areas can be coated with epoxy resin to further improve long-term corrosion resistance. Extreme exposures combining damp conditions with ammoniacal copper arsenate (ACA) or chromated copper arsenate (CCA) treated wood may call for more costly stainless steel plates.

Anchoring Truss-Frames

The method of anchoring a structure to its foundation is a potential weak link in any system, including the TFS. In most TFS structures, a sill plate can be anchored to the foundation, then each truss-frame securely anchored to the sill plate. Sills are conventionally tied down by threaded anchor bolts embedded in the foundation wall. Straps may also be placed in concrete for securing sills. Such fasteners should extend at least 7 inches into cast concrete and 12 to 18 inches into masonry block walls or bond beams. Other sill-to-foundation anchors include caulking anchors, expansion anchors, and powder-actuated studs, although some of these may not comply with applicable codes. Anchorage of truss-frames to a concrete beam without a sill plate is shown in Figure 32.

In the case of the All-Weather Wood Foundation, the foundation’s cap plate takes the place of a sill plate. The cap plate must be well anchored to the wall below, usually by plywood sheathing.

Perhaps the most effective method of tying a
truss-frame to a wood foundation or sill plate is by a structurally acceptable sheathing or siding such as plywood securely nailed to the sill and the truss-frame. Metal strapping or metal framing anchors can also provide code-acceptable tie downs.

Toe-nailing does not furnish adequate truss-frame anchoring to the sill plate unless a supplementary anchor such as sheathing or metal ties is applied. It would be deplorable to tie down integrated truss-frames with a poor anchoring system.

Figure 32. Truss-frames secured to a concrete frame foundation with strap anchors. (Forest Products Laboratory)

Partial truss-frames applied to slabs-on-grade or to conventional wooden decks, as in upper story construction, also need adequate anchorage. Again, this is usually provided by code-accepted sheathing or siding properly nailed to both sills and studs. An acceptable alternate is the use of metal straps or framing anchors.

Firestopping and Draftstopping

Building codes vary in their requirements for firestopping and draftstopping in concealed spaces within a building. Model codes and local codes are being updated to consider new construction techniques. Both modes of fire blocking are intended to limit the spread of a fire through structure cavities to protect an escape route for inhabitants and to permit safer access for firefighters. The National Forest Products Association (NFoPA) developed recommended fire-blocking practices to be considered in updating the model building codes*. NFoPA recommendations may be used in the absence of more detailed applicable code requirements.

Firestopping and draftstopping limit the spread of fire by preventing the movement of flame, hot gases and smoke to other areas of the building:

- Firestops limit movement through relatively small concealed passages such as under stairs and inside walls. Firestopping material may consist of at least 2" nominal lumber, two thicknesses of 1" nominal lumber with broken lap joints, or 3/4" plywood, or other approved materials.

- Draftstops limit movement through large concealed passages such as open-web floor trusses. Draftstopping material may consist of at least 1/2" gypsumboard, 3/8" plywood, or other approved materials usually applied parallel to the main framing members.

Firestopping is required at both ceiling and floor levels in concealed spaces of stud walls. In the TFS it is usually provided by the upper and lower spacer blocks, as shown in Figure 13.

Draftstopping is recommended in concealed floor or ceiling cavities parallel to the floor trusses, as shown in Figure 33. At least one draftstop is recommended for each floor or ceiling truss cavity. In a large house, the isolated cavities should not exceed areas allowed by the applicable code or NFoPA recommendations.

In multi-family dwellings, the NFoPA recommends that, unless approved sprinklers are installed, draftstops should be provided in floor

Thermal Design

The Truss-Framed System accommodates all popular energy design features including:

- Mineral wool or cellulose insulations, either blanket or loose fill.
- Foam insulation board sheathing.
- Infiltration barriers.
- 2x6 wall studs.
- Double-wall, box-stud and envelope house designs.
- Raised or "energy" trusses for full ceiling insulation.
- Passive and active solar systems.

Insulation, vapor retarder and caulking application recommendations for TFS are similar to those for conventional wood frame construction. The only notable - and a favorable - difference is in the application of under floor insulation. In truss-framed construction, floor insulation can be applied in the plane of the floor truss bottom chord. Because side walls of the truss cavity can also be insulated, the truss cavity's mechanical installations are enclosed within the building's thermal envelope. This arrangement reduces energy losses from heating/air conditioning ducts and hot water systems. It also reduces the possibility of frozen water pipes.

The TFS has fewer thermal bridges that short-circuit heat flow than does conventional construction. Such thermal bridging members are represented by second top plates, let-in braces and band joists, which are not needed in truss-framed structures.

Mechanical Equipment Installations

The Truss-Framed System provides underfloor chases for convenient mechanical installations. Electrical, plumbing, and HVAC components should not be installed in exterior walls unless absolutely necessary. Installations usually can be planned so as to require no cutting of structural members. Fixture locations can be selected to provide clearance between structural members and ducts or fittings such as closet flanges. Time-consuming joist drilling is not required in the TFS because floor framing is of open web construction. Plumbing-supply pipes in exterior walls are more vulnerable to freezing and, are likely to create thermal bridges. HVAC ducts in exterior walls are less subject to heating (or cooling) losses to the outside and also interrupt the insulation envelope.

Mechanical services can be distributed in several ways:

- Floor trusses can be designed with duct races, as shown in Figure 34.
- Open-web floor trusses can accommodate small ducts without designed-in races. Trusses are closely spaced
and, if the duct size is a close fit to the web openings, it will be difficult to string lengths of ducting into the cavity. Temporary openings can sometimes be provided through the end walls to simplify the task.

![Diagram of Opening to accommodate air duct](image)

**Figure 34. Air duct installation in a floor truss cavity.**

- The floor-truss cavity can provide an ideal HVAC underfloor plenum.* It can be used as a supply plenum combined with conventional return air ducting or as split supply/return air plenums.

- Conventional dropped-soffit duct races or plenums can be used.

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CONSTRUCTION
A significant key to the potential benefits offered by the truss-framed system is effective coordination of the fabrication, transportation, and erection stages. The advantages can be further enhanced by cooperative effort between the truss fabricator and the builder. This section discusses the major considerations in fabricating and erecting truss-frames.

**FABRICATION**

Truss-frames should be fabricated by a truss manufacturing plant. Criteria and procedures should follow Truss Plate Institute or similar design and fabrication specifications including quality-control requirements. If the plant's fabricating equipment cannot process full-height or full-size truss-frames, they can be manufactured in sections and assembled afterward, either in the plant or on site. For self-help or isolated construction projects,* properly designed truss-frames with nail-glued plywood gusset plates can be used.

Fabricators should not make substitutions for specified connectors without approval by the design engineer. Even heavier gauge plates cannot be routinely substituted, as they may have lower gripping values because of different features.

Typical truss-framed fabrication practices are shown in Figures 35 and 36.


**TRANSPORTATION**

Possible constraints on truss-framed configuration and size imposed by transportation factors have already been discussed from the designer's standpoint. Special considerations of concern to the fabricator may include:

- Loading truss-frames on trucks at an angle to improve road clearances.
- Obtaining greater road clearances for secondary road routings.
- Shipping truss-frames knocked-down to partial truss frames for final assembly on site. (In these instances the field connection must be specifically designed and the field assembly supervised or stipulated by the truss manufacturer.)

Trucking options for maintaining road clearances are shown in Figure 37.
HANDLING AND STORING

Truss-frames can be awkward to handle and vulnerable to damage if handled incorrectly as indicated by Figure 38. They should be protected from excessive lateral deformation, which can lead to damaged joints or members. Manual handling requires a crew of at least five to cover intermediate lifting positions and to avoid undue distortion of the truss plane. Truss-frames should be unloaded and stored only on relatively flat areas free of obstructions to avoid distortion of joints, as shown in Figure 39. With sufficient care truss-frames can be handled and stored either lying horizontally or standing in the vertical position.

For horizontal storage, stacked truss-frames should be placed on enough supports to protect them from unsupported long spans and ground moisture. For vertical storage, they should be adequately blocked or braced to prevent toppling. In either case, they should be covered for protection from the elements and adequately ventilated to prevent moisture build up.

Figure 38. Bending of truss-frames in handling. (EC-ON-ERGY Corp.)

Figure 39. Truss-frame storage in horizontal position. (EC-ON-ERGY Corp.)

A. Loaded vertically
B. Loaded at an angle to reduce height and width.
C. Loaded flat

Figure 37. Trucking options for 14- and 15-foot truss-frames.
ERECTING TRUSS FRAMES

Speed of erection is a major benefit of TFS construction. Erecting the unitized frames completes the assembly of floor, wall, and roof framing in a single operation. An entire building can be erected almost as fast as conventional roof trusses can be set. One experienced TFS builder reported that he erected the frames for a typical house in 90 minutes and had it under lock and key that same day. Another reported that his experienced production crew of four erected two houses in one day. The erection task includes three operations: placing, aligning and bracing.

Placing

In the placing operation, the truss-frame is lifted from the stock pile and located in its approximate final position. This can be done in several ways:

- Carrying and tilting-up into position. This usually requires a crew of five to avoid undue distortion of the truss-frames.

- Mechanical erection with a light crane, as shown in Figures 40 and 41. A crew of three plus a crane operator is commonly used.

- Mechanical setting with a fork lift, if the ground level is accessible to the fork lift truck. Low foundations or wide openings such as garage door openings can provide such accessibility, as shown in Figure 42.

During loading, unloading and placing operations, control and safety can be improved by using a long-handled quick-disconnecting clamp such as the one shown in Figure 43.
Aligning

The task of aligning truss-frames is simple but it is essential that each step be executed carefully. The first end wall is erected and exactly squared and anchored to the foundation. It is plumbed in the center and at each end, and braced to assure it is precisely vertical. The plumbing operation requires a heavy-weight carpenter’s plumb bob; a spirit level is not sufficiently accurate. Temporary braces can be adjusted and shimmed to hold the end wall rigidly vertical. Adjustable framing braces can simplify the aligning task. The first truss-frame is also squared and plumbed.

NOTE: THE FIRST END WALL AND ITS ADJACENT TRUSS-FRAME MUST BE PRECISELY SQUARED AND PLUMBED TO SERVE AS A GUIDE FOR THE REMAINING TRUSS-FRAMES.

Subsequently erected truss-frames are spaced and squared by means of precut spacer blocks installed near the top and bottom of each stud as shown in Figure 12. The lower spacer blocks in Figure 12 are cut shorter than actual truss-frame spacing to allow for the thickness of truss plates and/or anchor plates. Matching edges and corner of wall sheathing panels is helpful in aligning truss-frame studs, but every truss-frame should be checked for alignment with a carpenter’s spirit level. Every fourth truss-frame erected should be plumbed at the center and at both walls to assure that accurate alignment is being maintained, as shown in Figure 44. Flat metal shims may be applied to correct spacing, or over- or under-length spacer blocks can be cut. If non-standard spacer blocks are precut, they should be prominently marked to identify their different lengths.

Reusable spacing fixtures as shown in Figures 45 and 46 can assist in aligning floor trusses while the floor sheathing is applied, however they should not be used as substitute for accurate location marks along each sill plate. Small inaccuracies in location can be either compensating or cumulative. In the absence of direct layout marks, cumulative errors could creep in.
Figure 44. Aligning and plumbing truss-frames. (Forest Products Laboratory)

Figure 45. Removable fixture for aligning floor trusses before sheathing is applied.

Figure 46. Aligning floor trusses for application of sheathing. (Forest Products Laboratory)
Bracing

Temporary bracing serves two purposes:

- to secure truss-frames in their design positions until permanent bracing is applied.
- to prevent a potential erection disaster of plane structures - domino collapse. This possibility of progressive collapse must be prevented until permanent bracing is secured. Failure to do so could have embarrassing, even fatal results.

Temporary bracing starts with bracing the first end wall. An example of temporary bracing is shown in Figure 47. Any brace that could undergo compression must be constrained from bowing laterally. Lateral buckling would reduce or destroy the compressive strength of such members.

CAUTION: TEMPORARY BRACING MUST BE CAPABLE OF RESTRAINING MOVEMENT IN ANY DIRECTION, AGAINST ANY WIND LOAD, WORKMAN AND EQUIPMENT LOAD, OR ACCIDENTAL IMPACT UNTIL THE PERMANENT BRACING IS IN PLACE. PARTICULAR CARE MUST BE EXERCISED IN LOOSENING TEMPORARY BRACING IN ORDER TO ADJUST, REPLACE, OR INSTALL PERMANENT BRACING.

Permanent wall sheathing should be installed as soon as the first end wall and first truss-frame are aligned, as shown in Figure 49. By the time an end wall and two succeeding truss-frames are wall-sheathed and anchored on both sides, the sheathed frames are self-supporting. The wall sheathing should be applied to subsequent frames as they are erected. It may be advisable to provide temporary bracing between truss-frames before application of sheathing, as shown in Figure 48.
Wall sheathing or single-layer siding must be:

- Code approved material to develop adequate racking strength.
- Anchored to truss-frames and sill plates using code-specified nail spacing.

Permanent bracing, including wall sheathing or siding, roof sheathing, floor sheathing and lateral bracing, must be installed as specified by the structural designer. See the permanent bracing discussion in the DETAILS section.

SUMMARY

From the standpoint of the completed assembly, there is little difference between truss-framed and conventionally-built light-frame wood houses. The TFS uses the same components, such as roof or floor trusses, and is designed to the same code requirements as is conventional construction. The truss-framed house benefits from better structural performance attained with less material than a comparable stick-built house assembled with even the best workmanship. The feature most appreciated by the builder and the home buyer, however, may be the acceleration of the construction process permitted by this method. As compared to panelized construction, the TFS offers a new option in prefabrication for builders who want to improve their production efficiency in the rough framing stage while maintaining full control over the finishing stages.