Clear-span buildings are becoming quite popular for many building needs and uses. The clear-span feature results from using trusses for the roof support and permits large amounts of open floor space without obstruction by interior posts, braces or supports. Construction costs for trussed-roof buildings are very competitive with and often-times less than conventional post-supported structures for widths 24 to 50 feet and greater.

**What is a Truss?**

A truss is a pre-assembled fabrication of wood, steel, or aluminum members designed to support a building's roof and ceiling loads over great spans. All the weight of the roof is transferred to the sidewalls and from there to the ground or building foundation.

**Obtaining Trusses**

Many building suppliers and contractors are now equipped with facilities for rapid fabrication of wood trusses. Some companies make metal trusses. Blueprint plans for several build-your-own wooden trusses are available from the Plan Service, Agricultural Engineering Department, University of Kentucky, and other agricultural service agencies. Only plans from reliable sources should be used, and then all instructions should be followed accurately during fabrication to obtain strong and durable trusses (see Figure 1). In most cases, prefabricated trusses can now be purchased for about the same cost as materials and labor for your own fabrication, thus you may be wise to buy them ready-made.

**Wall Support for Trusses**

Trusses are most often used with pressure-treated poles set in the ground or with concrete block walls. Use of trusses with tall conventional posts set on concrete or stub piers is not recommended, as extensive bracing is required to provide proper strength, thus defeating much of the clear-span feature and construction economy. Trusses should be used with stud-wall type construction only when there are one or more well-braced cross-wall partitions spaced a distance equal to the span width (such as with

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Charles E. Barnhart, Director of Cooperative Extension Service, University of Kentucky College of Agriculture.
residential construction) or when there is a "knee-brace" every six to eight feet from the truss to the side-wall, as with properly-designed animal or poultry facilities.

TYPES OF TRUSSES

There are many types of trusses. Some of the more popular types are shown in Figure 1.

CONSTRUCTION MATERIALS

For wooden construction, good quality kiln-dried, dressed lumber, or air-dried planed native lumber is required. Standard or construction grade fir, No. 1 or 2 Southern yellow pine, or equivalent grades and species are generally specified. A single knot or other wood defect in a joint or other critical place can seriously weaken a truss. Joint construction methods and materials are also very important.

JOINT CONSTRUCTION METHODS

Various joint construction methods that can be used include: 1) split-ring and bolt connectors; 2) all-nailed lapped-member joints; 3) all-nailed wood gusset joints; 4) glue-nail wood gusset joints; 5) nail-on metal plates; and 6) toothed metal plates pressed into the wood. Method (6) is used almost exclusively by commercial fabricators who have large hydraulic presses or rollers for making the joints. Method (5) is a newer design procedure that is easy to do and relatively economical (new Plan Service blueprints by the Agricultural Engineering Department show this method—see Figure 2). Method (4) has had widespread use but is being replaced by (6) and sometimes (5). Methods (1), (2) and (3) are not as popular due to the rather large and cumbersome joints that result. All the above joints can be made strong enough for a particular design, but methods (4), (5) and (6) provide the greatest strength with the smallest joint size.

HOW TO ORDER OR SPECIFY TRUSSES

Five main factors are required to describe a truss for a given use. They are:
1. Type
2. Span
3. Roof slope (or pitch)
4. Spacing
5. Load rating

Type:
Most farm buildings use the Fink or Kingpost type. Unless there is a particular need for one type, either will work satisfactorily for most buildings.

Span:
The span of a truss is usually measured from outside to outside of the wall framing or supports. Wooden trusses can be built to span up to 60 or 80 feet; steel trusses can span even greater distances. The most common distance for farm buildings is from 24 feet to 50 feet.

Roof Slope:
A roof slope of 4:12 (4 inches of rise to 12 inches of horizontal run) is most common. Steeper slopes (5:12, 6:12, etc.) may be used if required, while a smaller slope greatly increases the load in the truss joints and members. For example, a 3:12 slope truss has approximately 40 percent greater force in its members than a similar 4:12 slope truss and thus becomes rather bulky and costly to construct for large load ratings or wide spans.

Spacings:
Trusses for farm buildings are commonly designed and built for 2- to 8-foot spacings. The narrow spacings are used when covering is with solid or plywood roof decking and the wider spacings are selected for use with 2" x 4" or 2" x 6" roofing purlins with metal roofing. Trusses should not be spaced farther apart than their designed spacing, or serious overloading can occur and cause failures.

Load Rating:
Many trusses are designed and built for specific load ratings. The main loads are: roof structure, snow and ice, wind, ceiling, and special loads.

The roof structure load includes the truss weight, purlins or sheathing, and roof covering material. These are
often called the “dead loads” since they are a fixed and permanent part of the roof structure. The dead load for normal metal or asphalt shingle roofs used in agricultural structures varies between 5 and 10 pounds per square foot (psf). The actual dead weight can be calculated for any given structure system; however, an average value of 7 psf can generally be used for metal or shingle roofs.

**Snow, ice, and wind loads** vary throughout the year and are different for different parts of the country. These loads are often called “live loads” because they vary with changing weather conditions. Snow and ice loads are gravity loads and act as downward forces on the roof. Wind forces, however, can cause an uplift on the roof and thus must be considered as such in truss design and building construction. *Holding a truss or roof down may be just as critical as holding it up.*

Selection of the proper live load values for a building is quite important and realistic judgement should be used. If highly conservative values are selected, the structural system will be overdesigned and will be uneconomical. Care should be used, however, to include all loading of significance and to select the correct magnitude of loading so that the system is not under-designed. If uncertainty exists as to the true nature of the loads which will be imposed, it is better to make a conservative estimate than to risk the danger of a structural failure.

In the selection of design live loads, the nature or purpose of the building is also important. For instance, a more conservative selection of load values should be made for a building where a large number of people are to work than is necessary for a temporary structure or a structure for housing low-cost material such as hay. General recommendations are that permanent housing should be designed for severe loads, even though they may occur only once in a 100 years, when the housing is to be used by the public or where the economic consequences of failure would be serious. For buildings occupied by only a few people, the design should be based on 50 years; for livestock facilities, crop storages, processing facilities, and machinery storage, 25 years; and for low cost, short-life shelters, 10 years. Thus, the live loads for these various types of facilities and the frequency of severe loads should be known and is discussed in the following paragraphs.

**Snow Loading:** Weather records were analyzed to determine the probability of various amounts of snow occurring in several geographical regions. The analysis was based on the frequency of occurrence of various magnitudes of snow on the ground. For Kentucky, the following was reported:

<table>
<thead>
<tr>
<th>Years</th>
<th>Snow Load, Lbs. Per Square Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Ground: 15</td>
</tr>
<tr>
<td>50</td>
<td>Ground: 10</td>
</tr>
<tr>
<td>25</td>
<td>Ground: 8</td>
</tr>
<tr>
<td>10</td>
<td>Ground: 6</td>
</tr>
</tbody>
</table>

This means that once in 100 years a snow depth would occur which would cause a load on the ground of 15 pounds per square foot. However, within a 10-year period, you would only expect a snow load of 6 pounds per square foot. This, however, is not the load imposed on a building. Since the roof is above ground level, natural wind currents will cause less snow to fall on the roof than falls on the ground, with the actual amount being dependent upon the dryness of the snow. For wet, sticky snow it is recommended that designs be based on the assumption that 80 percent of the falling snow will accumulate on the roof.

**Roof slope** is also important. The steeper the roof, the smaller the amount of snow which will accumulate on the roof. For roof slopes of 3:12 or 4:12, which are commonly used in agricultural structures, an additional reduction of about five percent can be made. Thus, the adjusted snow load values which would actually apply to the roof of a typical building are given in Table 1 under the “Roof” column.

If a dead load, as previously discussed, is added to these figures, the design load for snow conditions is obtained. For Kentucky, the design load for even the severest snow probability would be less than 20 pounds per square foot. That is, 11.5 pounds per square foot of snow load, plus 7.0 pounds per square foot dead load. Most plans available from the University of Kentucky and from other public agencies for agricultural buildings are designed for a minimum of 20 pounds per square foot, and most are designed for 25 to 35 pounds per square foot. Truss plans for residential use are frequently designed for 35 to 40 pounds per square foot. Therefore, if available designs are followed, structural failure due to snow loading should not be a problem in Kentucky.

Ice loading sometimes occurs along with snow loading, but the maximum load, either alone or in combination with snow, is not considered to exceed the pertinent snow loads.

**Wind Loads:** A similar analysis to that described for snow loads was also made for wind loads. In this case, the probability of occurrence of various high wind speeds was determined. The values given are for a height of 30 feet. At lower heights a lower wind speed would be observed. Momentary gusts were excluded since buildings can with-
stand very short periods of wind pressures. Tornadoes were also excluded.

Table 2: Probable High Wind Velocities for Various Recurrence Intervals.

<table>
<thead>
<tr>
<th>Recurrence Interval</th>
<th>Wind Velocity, MPH</th>
<th>Pressure, Lb Per Square Ft., Perpendicular to Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>85</td>
<td>18.5</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
<td>16.4</td>
</tr>
<tr>
<td>25</td>
<td>70</td>
<td>12.5</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>9.2</td>
</tr>
</tbody>
</table>

The wind-speed data permit the calculations of the pressure which would be exerted on a surface oriented perpendicularly to the wind. As can be seen, these values are larger than the snow load values but occur in different directions and have different effects on a building.

Since many surfaces are oriented at some angle to the wind, especially roofs, the effect of the wind varies and oftentimes results in an uplift pressure rather than a downward force. Suction forces of the magnitude of 60 to 70 percent of the pressures in the above table are common. This means that uplift forces in the range of 10 to 12 pounds per square foot of roof surface are common. This magnitude of loading is equivalent to the snow load. It is acting, however, in the opposite direction. A particularly serious situation results with open-sided buildings or buildings where the doors are left open during high wind periods. Under this condition, a wind pressure can build up within the structure equivalent to about 0.7 of the pressure given in the above table. At the same time, a suction pressure of about the same magnitude can occur on the outside surface of the building. These effects are illustrated in Figure 3.

This high wind hazard accounts for the relatively large number of roof and structural failures which occur annually in Kentucky due to winds. Since wind hazard is the most serious problem in Kentucky, the anchoring of the roof system to the foundation to prevent uplifting must be equivalent to the support given to carry the "live" snow load. Consequently, the attachment of the purlins or roof girts to the rafters or trusses, of the trusses and rafters to the sidewall or plates, of the sidewall supporting posts to the foundation, must receive special consideration, which we shall discuss later.

Wind loads also represent another serious hazard, the "racking" or side load they exert on a building. The wind exerts a positive or pushing pressure on the windward wall and a suction or pulling pressure on the leeward wall. This tends to pull the building over sideways. Some form of diagonal or "knee" bracing must therefore be provided to resist this load. Such bracing must be provided in both the longitudinal and crosswise directions of the building. If properly installed, diagonal bracing can also contribute to the resistance of a building to the uplifting forces.

CEILING LOADS

Ceiling loads may range from a light insulation and vapor barrier load to heavy caged layers. Ceiling and insulation loads range from less than 1 psf for rigid insulation board to 2-3 psf for plywood and batt insulation or similar materials. Since the ceiling load is a dead load, it is often included in the total dead load.

SPECIAL LOADS

Frequently some animal facilities have additional loads suspended from the ceiling, such as caged layers in poultry houses or feeders and equipment in swine or other such facilities. It is very important that these loads be considered in an initial truss design and not added to just any existing truss. The added load can equal the original total truss design load. For example, several poultry house trusses have failed in the past because cages were added to trusses originally built to support only the roof, snow and ceiling insulation loads.

![Figure 3: Relative distribution of wind forces on a building.](image-url)
A summary of approximate loads for truss design and usage in Kentucky is given in Table 3.

Table 3: Summary of Approximate Loads for Truss Design and Usage in Kentucky

<table>
<thead>
<tr>
<th>TYPE LOAD</th>
<th>P.S.F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gable type roof, trusses 4' apart, 2&quot; x 4&quot; purlins</td>
<td>4-6</td>
</tr>
<tr>
<td>2' apart, metal roof</td>
<td></td>
</tr>
<tr>
<td>Gable roof, trusses 2' apart, sheathed with 3/4&quot; boards, 15-pound felt, 210-pound asphalt shingles</td>
<td>7-10</td>
</tr>
<tr>
<td>Snow and Ice (Kentucky, 50 year probability)</td>
<td>10-12</td>
</tr>
<tr>
<td>Wind (Kentucky, 50 year probability)</td>
<td></td>
</tr>
<tr>
<td>Note: Use proper design procedures for wind loads.</td>
<td>70-80 miles per hour</td>
</tr>
</tbody>
</table>

Ceiling:
- 3/8" plywood or 1/2" fiberboard, vapor barrier, and insulation: 2.5
- Rigid insulation board: 0.5-1
- Caged layers, each cage row with cages 2 high and 2 wide, with feed and water trough, litter board: 60-80 pounds per linear ft.

TRUSS LOADS AND STRUCTURAL FORCES

After the dead and live loads, type, span, and spacing have been specified for a truss, the actual design is done by a qualified person, usually a licensed engineer. Standard designs are then tabulated in booklet form for commercial fabricators or individual blueprints developed for build-your-own type trusses. The actual forces that can be created in a truss configuration are often diagrammed on the blueprint to show critical members and joint sizes. Figure 4 illustrates the tension and compression members and magnitude of load in each for a given truss design. Notice the forces the truss members and joints must withstand. The eave joint and the center splice of the bottom chord are the most critical joints. These large forces show the need for good quality lumber without defects, strong joint design and fabrication, and no damage during construction. Diagonal members must never be cut out of the truss for construction conflicts.

The most important load for the designer or actual builder to consider for construction is the truss reaction load at each end. This is the maximum load the truss must transfer to the sidewall if all the dead and live roof loads occur at once. Adequate support of the trusses is very important and yet is one of the commonest failures observed in clearspan roof construction.

TRUSS SUPPORTS AND ANCHORING

Clear-span farm buildings generally have pressure-treated poles set 4 to 5 feet deep in the ground for sidewall construction. The poles may be spaced 4 to 16 feet apart with a truss located at each pole and, for the wider spacings, one or more of the trusses spaced between the

TRUSS:
- 40' SPAN, RATED
- 27 psf @ 6' SPACING
- NO CEILING LOAD

Figure 4: Example of truss loads.
poles. Where trusses are spaced between poles, plate supports or girders are required between the poles to support these trusses. Blueprints should be followed in sizing and attaching these supports. As a supplement to blueprints, and to help clarify the size of truss supports required, Tables 4 and 5 provide handy references for normal applications. An example with Table 5 illustrates how to use the tables.

**Table 4: Truss Reactions At Each End of The Truss (Lbs.)**

<table>
<thead>
<tr>
<th>Design Load</th>
<th>Building Span (Ft.)</th>
<th>Truss Spacing (Ft.)</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>20</td>
<td>500</td>
<td>1,000</td>
<td>1,500</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Plus</td>
<td>24</td>
<td>600</td>
<td>1,200</td>
<td>1,800</td>
<td>2,400</td>
<td></td>
</tr>
<tr>
<td>Snow</td>
<td>28</td>
<td>700</td>
<td>1,400</td>
<td>2,100</td>
<td>2,800</td>
<td></td>
</tr>
<tr>
<td>Assumed equal</td>
<td>32</td>
<td>800</td>
<td>1,600</td>
<td>2,400</td>
<td>3,200</td>
<td></td>
</tr>
<tr>
<td>to 25 PSF*</td>
<td>36</td>
<td>900</td>
<td>1,800</td>
<td>2,700</td>
<td>3,600</td>
<td></td>
</tr>
<tr>
<td>(Total Load)</td>
<td>40</td>
<td>1,000</td>
<td>2,000</td>
<td>3,000</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>44</td>
<td>1,100</td>
<td>2,200</td>
<td>3,300</td>
<td>4,400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>1,200</td>
<td>2,400</td>
<td>3,600</td>
<td>4,800</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>1,250</td>
<td>2,500</td>
<td>3,750</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1,500</td>
<td>3,000</td>
<td>4,500</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>1,750</td>
<td>5,500</td>
<td>5,250</td>
<td>7,000</td>
<td></td>
</tr>
</tbody>
</table>

*25 PSF is a suitable roof design load for farm buildings under Kentucky conditions. Caged poultry loads require special designs.

**Table 5: Allowable Loads On Truss Support Members* (Load P is each truss reaction load from Table 1)**

<table>
<thead>
<tr>
<th>Pole Spacing (Ft.)</th>
<th>Member Size**</th>
<th>Simple Beam FF</th>
<th>3</th>
<th>2</th>
<th>P</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>6</td>
<td>272</td>
<td>408</td>
<td>543</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>472</td>
<td>708</td>
<td>944</td>
<td>1087</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>10</td>
<td>543</td>
<td>815</td>
<td>1087</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>769</td>
<td>1153</td>
<td>1537</td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>88</td>
<td>944</td>
<td>1417</td>
<td>1889</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>1137</td>
<td>1706</td>
<td>2274</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1010</td>
<td>1010</td>
<td>1537</td>
<td>2306</td>
<td>3075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>1537</td>
<td>2306</td>
<td>3075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1212</td>
<td>1212</td>
<td>2274</td>
<td>3411</td>
<td>4548</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1010</td>
<td>1537</td>
<td>2306</td>
<td>3075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1212</td>
<td>1706</td>
<td>2558</td>
<td>3411</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Load rating based on dimension lumber having a fiber stress rating of 1750 psf or better for maximum bending, and dimensions of dressed lumber.

**6 = 2" x 6"; 66 = two 2" x 6"; etc. All members to be installed on edge and attached with proper type and number of fasteners for adequate joint strength.

**Example:** What size truss support plates would be required for a 40-foot span, 25-pound-per square-foot (PSF) roof design load, trusses spaced 4 feet apart, with poles spaced 12 feet apart? From Table 4, find the truss reaction "P" at each end of the truss, which is 2,000 pounds for this example. From Table 5, using the 12-foot spacing group and the column showing two trusses between poles, the truss reaction load of 2,000 pounds requires two 2" x 12" members for adequate design strength.

**TRUSS SUPPORT PLATE ATTACHMENT**

Attaching the trusses and truss support plates to the poles is the next important construction step. Traditional construction methods often involved notching the member into a post, but present-day labor and construction costs prohibit the notching technique. Thus, loads are transferred to supporting poles through nails, bolts, supplemental scabs or other type fasteners as illustrated by Figure 5. Again...
blueprints should specify these joint construction details, but Table 6 is listed as a reference for typical fastener design loads and estimating joint strengths.

Table 6: Design Loads of Selected Nails and Bolts for Pole Building Construction.

<table>
<thead>
<tr>
<th>Type Joint</th>
<th>Design Load per Fastener in Lateral Loading (Lb.) Nails* Bolts**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size &amp; Load</td>
<td>Size</td>
</tr>
<tr>
<td>2&quot; lumber</td>
<td>16d</td>
</tr>
<tr>
<td>round or square pressure treated poles.</td>
<td>40d</td>
</tr>
<tr>
<td>60d</td>
<td>277</td>
</tr>
</tbody>
</table>

*Pertains to ring-shank or screw-shank nails only. Smooth-shank spike nails are not recommended in pressure treated wood. If used, reduce load by one-third to one-half.

**Single shear is the condition where 1 bolt is through 2 members, each being pulled in opposite directions. Double Shear is where 1 bolt is through 3 members with the center member being pulled opposite to the outer two.

In the example of Figure 5 where the truss loads are transferred to each pole, the plate-to-pole joint must support a total of 6,420 pounds. From Table 6 the number of 40d nails required to safely transfer this load is twenty-nine (6420 ÷ 220 = 29). Other fasteners could also be used. (How many pole barn joints have you seen with about one-third or one-half this number of nails? Such under-sized joints seriously affect the strength and safety of the structure.) Longitudinal bracing as discussed can help support this load. Other techniques are also frequently used.

Some commercial pole barn builders use 7', 8', or 9' pole spacing and put a truss only at each pole. The truss-to-pole fastening must still have adequate strength as determined above.

Figure 6 shows a typical support plate attachment for truss construction.

In poultry houses where trusses support caged layers and equipment, each truss may be positioned directly on a pole or post at 4- or 5-foot spacings, thus achieving direct load transfer without heavy plate supports. Fewer nails are used, most of which are for side scabs or truss anchoring to prevent movement off the post and to provide holddown anchorage per the discussion on wind uplift.

WIND UPLIFT STRESSES

A wind blowing 80 miles per hour will cause an uplift stress of 900 pounds on a 40 foot wide truss with 6 foot spacing. Trusses that are not located at poles must be securely anchored to the plates as shown by Figure 5. A truss anchor block can be placed on each side of the truss and nailed to the truss and plates. For the 900 lb. uplift force, five to six of the 40d screw shank nails, or an equivalent strength of smaller nails, could be used to nail the blocks to the truss and the same number can be used for nailing the blocks to the truss support plates to produce the total joint load transfer. The number of nails for other truss spacings or wind uplift loads would be determined similarly.

PURLIN ANCHORAGE

Purlins, or roof girts, are typically spaced two feet apart. For trusses 4 feet or less apart, 2" x 4" purlins are placed flat-ways. For truss spacings greater than 4 feet but less than 8 feet, 2" x 4" purlins are placed on edge. For truss spacings 8 feet or greater, 2" x 6" and larger purlins on edge are necessary and are shown by proper blueprints.

Metal roofing is normally applied over the purlins. The lifting wind stresses first attempt to pull the roofing material off from the purlins. Metal roofing must be nailed carefully with screw- or ring-shank roofing nails according to the manufacturers' instructions to withstand these lifting stresses. As a general rule, 100 nails are required for each 100 sq. ft. of roof surface. A lot of loose roofing is largely
Due to improper and inadequate nailing rather than poor roofing material.

Assuming the roofing is attached securely to the roof purlins, then the purlins must withstand and transfer the lifting wind stresses to the truss upper chords. The attachment of roof purlins to the trusses can be critically weak joints in the roof frame. For the previous truss example, an 80 mile per hour wind causes 90 pounds of uplift for each joint between a purlin and the truss upper chord. The withdrawal resistance of 16d screw-shank nails is approximately 75 pounds each (50% increase above common spikes), thus at least 2 would be required per joint. This is possible for 2" x 4" flat-ways, but, on edge, the situation is different. Forty or 60d nails would be required to drive through the edge of a 2" x 4" and penetrate the top chord. 60d screw shank nails hold approximately 105 pounds each, thus one would equal the 90 pounds required. Since “toe-nailing” is an unreliable joint and strength data are not available, toenailed joints would be unpredictable and are to be avoided if at all possible.

Figure 7: Illustration of how the pole and truss construction is stiffened at the top with adequate knee braces.

TRUSS BRACING

The bracing of trusses is essential, both during construction and afterwards, especially for wide and/or long buildings. If one truss is allowed to buckle or fail in any way, it may well cause several or all to fail in a “domino” manner. Adequate bracing can do three main things for a building:

1. It can help obtain the full available strength of the materials used in the building.
2. It can make the building act as an integral unit in resisting certain loads rather than each element separately resisting some load.
3. It improves the rigidity of the structure.

Bracing in most clear-span buildings is not intended to interfere with the operational conveniences, but to strengthen the building in an efficient and simple manner.

Three types of bracing may be required: 1) “knee” bracing; 2) diagonal or “sway” bracing; and/or 3) longitudinal “runners.”

Pole-type buildings produce a stronger sidewall and overall structure than the older post-pier types because the poles are set in the ground. However, some knee bracing is still necessary in most constructions to ensure a strong building. Knee bracing as shown in Figure 7 helps reduce the movement of the poles at the top and strengthens the sidewalls against wind forces. The higher the sidewalls, the more essential are the knee braces.

Longitudinal knee braces, sometimes called “Y” braces, are also used along the sidewall. These provide longitudinal rigidity to the building and can help support the truss load, thus reducing the maximum design of the truss support plates.

Trusses supported on concrete block walls do not require knee braces. The main requirement is that the top plates be properly bolted to the blocks with 16- to 24-inch long anchor bolts every 4 to 6 feet, and that the trusses be securely attached to these plates. Truss anchor brackets, clips or tie-down straps are required. Toe-anchor brackets, clips or tie-down straps are required. Toe-nailing is inadequate to withstand wind uplift forces. Toe-nailing also may damage the critical heel joint if large nails are driven through the joint. When concrete block walls are higher than 8 to 10 feet, pilasters should be used to stiffen the wall against buckling and side wind forces. Refer to concrete design data or appropriate persons for details of pilaster size and spacing.

Trusses should not be used in long or wide buildings having studded walls or posts-on-piers unless extensive knee braces are used to prevent wall overturning. Such construction should be limited to houses comparable in size to dwelling houses. End walls should be braced, and interior cross-partitions should be used to ensure safe use of trusses on studded walls.
Figure 8: Proper truss bracing includes diagonal "sway" bracing down the center of the trusses, or diagonal cross-bracing under the top chords plus longitudinal runners on the bottom chords (when a rigid ceiling liner is not used).

Trusses are held rigid by bracing as shown in Figure 8. The "sway" or "X" bracing down the center prevents the trusses from collapsing by the "domino effect." When the truss does not have a center "Kingpost" for the sway bracing, use the diagonal cross-bracing underneath the truss top chords at the ends and at 40- to 60-foot intervals. This bracing also holds the trusses vertical throughout the building's life, ensuring their maximum strength.

**Important:** Bracing is no stronger or better than the connection between the joint and member. Build good joints, and the braces will do their job.

**TRUSS FAILURES**

Most truss failures are "man-caused" rather than weather-caused. This means that carelessness or short cuts in construction create weaknesses in the trusses that result in failures during the first big wind or snow. We are fortunate in Kentucky to have known of only a few truss and building failures. Other states have reported on the inspection of numerous truss failures which can be grouped into two general categories:

1. **Design misuse**, and
2. **Poor construction**.

Design misuse means using trusses in ways for which they were not designed or intended. Examples are:

1. Spacing trusses wider than designed (putting 2-foot trusses on 4-foot spacing, or 4-foot trusses on 8-foot spacing).

2. Extending the top chord and/or raising the lower chord so the "heel" joints are above the eave plate supports to give more overhead clearance. **THIS IS NOT RECOMMENDED!** Excessive stresses are created in the eave joint and top chord. For example, raising the bottom chord only 8 inches in a 40-foot truss would require a top chord change from a 2 x 8 to a 2 x 12 member to adequately withstand the forces between the truss heel joint and the plate support!

3. Adding heavy ceiling loads, such as caged layers, to a truss designed and installed for normal roof loads only. Caged layers could increase the truss load by approximately 50 to 100 percent.

4. Cutting diagonal web members to aid installation of special equipment (ducts, fans, etc.).

5. Adding extra splices or joints that are improperly made or positioned and not specified on the blueprint.

Poor or careless construction often includes the following factors that contribute to failure:

1. Use of inferior grade lumber having a lower stress rating, extensive knots, splits, or similar defects, especially in the lower chord.

2. Weak joints resulting from too few nails, not enough glue, a bad glue mixture, too small gusset plates, or gusset plates not positioned properly over the joint.

3. Lack of bracing during construction.

4. Pole and plate supports not adequately sized and fastened to withstand the loads and wind uplift.
Cost

Truss costs, of course, vary according to location, material, labor costs, quantity, and delivery distance. Check several area suppliers for your needs and delivery schedule. Material costs for build-your-own types are approximately two-thirds the prefabricated cost, but are probably not worth the difference after considering labor costs and jig requirements for good fabrication results. Build-your-own trusses may be feasible in locations where the availability of prefabricated trusses is limited or particularly costly, or for special trusses that are not readily available from the fabri

Blueprints for several build-your-own trusses are available from the Plan Service of the Agricultural Engineering Department at a small charge per plan. Several farm building blueprints include the truss plan with the facility and are designed for the convenience of the person in deciding whether to buy or build the trusses and to help ensure the proper type if buying. Also, information on erection of pole-frame, clear-span buildings is available.