Clear Span Roof Construction
Michigan State University
Cooperative Extension Service
Farm Science Series
Replaces Farm Building Series Circular 732
James S. Boyd, Agricultural Engineering
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FARM SCIENCE SERIES
(Replaces Farm Building Series Circular 732)

CLEAR SPAN ROOF CONSTRUCTION

James S. Boyd
Agricultural Engineering

THE USE OF roof trusses and clear span roof construction in Michigan farm buildings is an accepted practice. They eliminate interior poles and thus allow the farmer a wide range of uses.

Clear span construction has the following advantages over other types of buildings:

1. **Machinery Storage**
   - better use of available space
   - easier in-and-out movement of machinery
   - allows for either side or end openings
2. **Livestock Shelters**
   - easier to clean mechanically
   - fewer injuries to livestock
   - better adapted to all types of livestock
   - no restrictions on shape and size of pens
   - easier placement of feed bunks
   - can be either environmentally controlled or a cold structure
3. **Hay Storage**
   - can be adapted to self feeding
   - easier handling of bales, both manually and mechanically
4. **Grain, Fruit and Vegetable Storage**
   - large open areas are convenient for bulk storage of grain and vegetables – machinery can be stored when grain is removed
   - convenient for handling fruit and vegetables in boxes with fork-lift trucks
   - can be insulated and used as refrigerated storage

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DESIGNING CLEAR SPAN BUILDINGS

Wooden roof trusses are the basic items in clear span construction. Trusses designed by Michigan State University are for 4 feet on center spacings. Michigan roofs should be designed to hold a total weight of 30 psf. Different truss designs can be used if they will withstand the design load.

The design on the left of Fig. 1 is not recommended. The truss on the right is a proper design and will withstand recommended design loads for Michigan. When a truss is built with the same size material but with a raised lower chord, as shown on the left in Fig. 1, it will hold only about one-seventh of the design load. (*Lumber in the truss should be construction grade Douglas Fir or No. 2 kiln-dried Southern Yellow Pine or equivalent.*)

The weakest parts of most farm buildings are the joints. With truss construction, secure joints can be made by using split rings or glue to utilize the full wood strength. Nails and bolts are less-effective fasteners. Nails become ineffective when the wood splits.

Split-ring connectors have been used, but they will require more labor. The resulting truss is difficult to stack because the joints must be lapped. At some joints, there may be as many as four members overlapping each other. Two sizes of split rings are used, 2½ in. and 4 in. The smaller rings are used when 2 x 4 material is used in the truss. When the smallest member is 2 x 6, the larger ring can be used. A special grooving tool is required since the ring must fit tightly into the groove. After the groove is cut, the ring is inserted between the members and a 9/16 in. bolt used to hold the members together. Advantages of ring bolt trusses: (1) can be used in all types of weather and (2) can be used with rough sawn lumber.

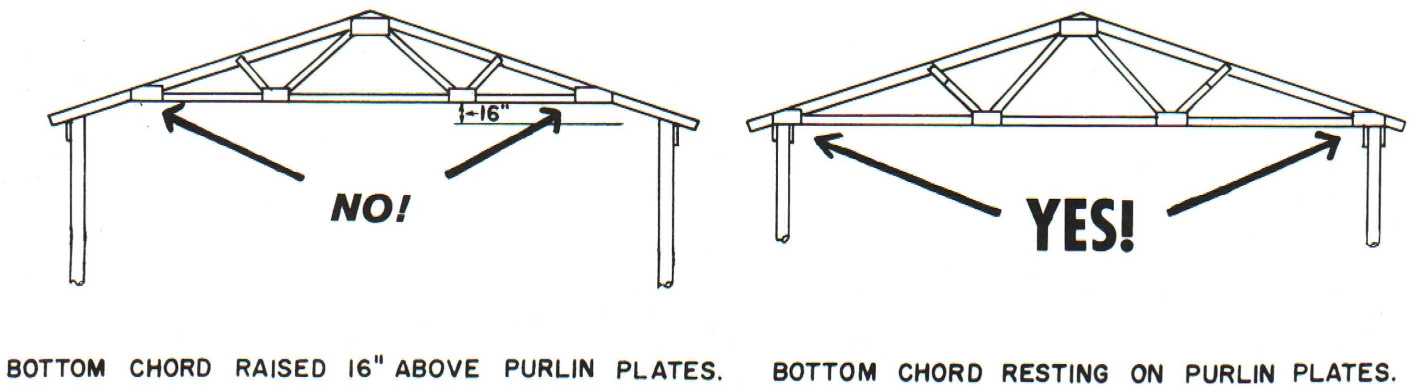
On larger spans, the joints at the heels of the truss usually have enough stress to require two rings, Fig. 2.

Figure 2 — One-2½ in. split ring was used on this joint where at least two rings should have been used.

Glue-Nailed Trusses

Making a glue-nail truss is different than making a ring-bolt truss because all members are in the same plane. Plywood pieces called gusset plates are put on each side of the joint and fastened in place with glue and small nails. After all of the members for one truss have been cut according to the plan, they should be assembled on a level floor to be sure they all fit together and result in the correct overall dimensions. This first truss can then be used as a pattern to cut the other trusses. (*Plywood used for gusset plates should be exterior type ½ in. or ⅝ in. thick.*)

Figure 1 — Two types of roof trusses used in Michigan Farm Buildings (incorrect - left; correct - right).



The first truss is laid out on the floor or on benches, Fig. 3, and the glue is applied to both surfaces to be glued. Powdered casein, which is mixed with water is the type of glue most often used. The powder should be the kind designed for aircraft, one that contains a mold inhibitor. Figure 4 shows a joint which apparently failed due to mold. Resorcinol-resin glue or urea-formaldehyde glues can also be used.

The glue that is used should:

1. Be *thermosetting* so that it will not soften when the temperature rises. Many of the common plastic glues used in shops are *thermoplastic* (change shape under heat), and should not be used.
2. Be gap-filling to fill small spaces between the two surfaces and not shrink when it sets.
3. Be moisture resistant, but not necessarily water proof.
4. Set at room temperatures from 50° to 70° F.

The pressure required to hold two pieces together while the glue sets is supplied by 4d or 6d nails spaced 3 to 4 in. apart. When the gusset plates have been nailed, glue should squeeze out from all sides. This assures that complete contact has been made between gusset plate and member, Fig's. 5 and 6.

After gusset plates have been applied to one side, the truss can be turned over carefully so that glue and gusset plates can be applied to the second side, Fig. 7. The truss can now be moved to a dry place for at least 24 hours storage when the temperature is 70° F or above. When the temperature is below 50° F, trusses should be stored several days before erecting. Glued trusses should not be assembled when the temperature is below freezing.

Metal Plate Trusses

Often it would be desirable if the trusses could be purchased ready-assembled. Factory assembly using glue and nails is not practical. Punched metal plates are suitable for factory fabrication and are rapidly being adapted to farm buildings. These trusses are designed for specified truss spacing and design loads.

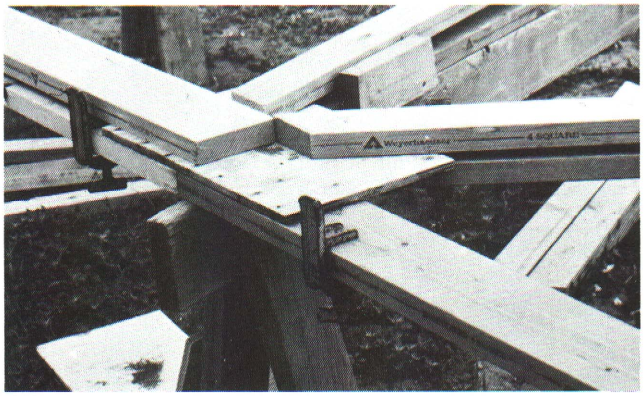


Figure 3 – Use one truss as a pattern. Cleats nailed to side of pattern truss facilitate assembly.

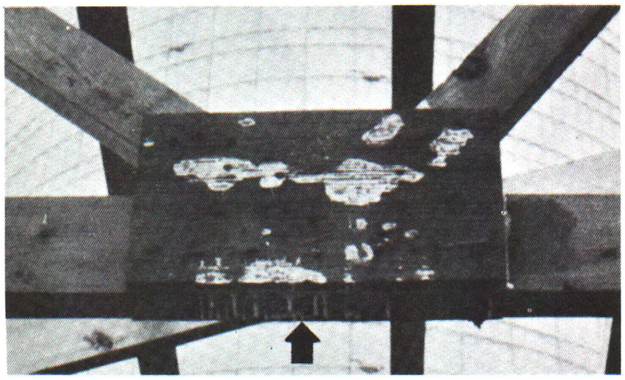


Figure 5 – Evidence of a well-filled glue joint – glue running down the side of the 2 x 4.

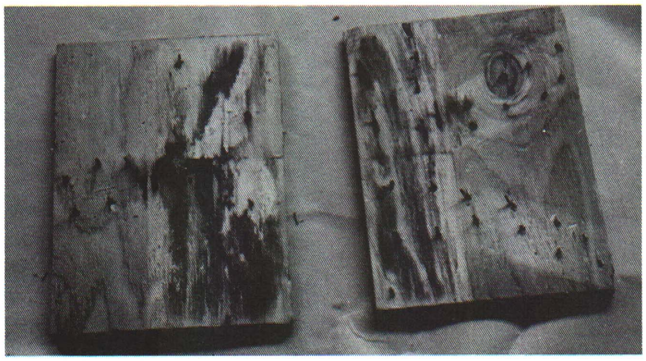


Figure 4 – Gusset plates taken from a truss showing the mold formed in the glue – indicates very little contact area.

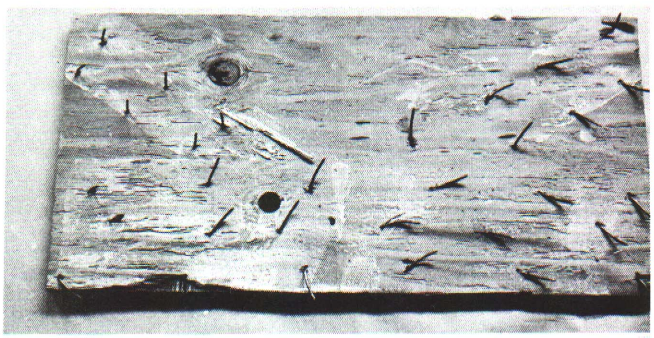


Figure 6 – A gusset plate from a building that failed. About a 10 to 20 percent glue contact area is apparent from the wood fiber failure. Glue did not squeeze out of this joint.

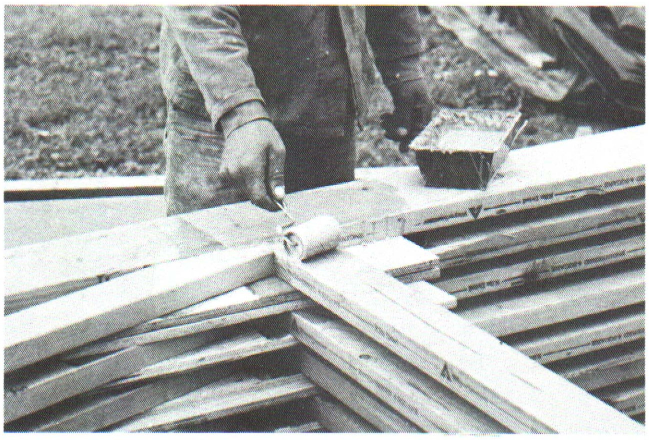


Figure 7 — Applying glue with a paint roller. A paint brush can also be used.

Be sure these specifications are followed. Do not space the trusses farther apart than specified by the design, and request a design sheet for the truss showing a 30 psf design load. One advantage of these trusses: they can be assembled in all kinds of weather.

Erection of Trusses

Clear span trusses can be put on all types of walls. The trusses are usually hoisted in place by an "A" frame built on the front of a farm tractor. If the wall is 10 to 12 feet high, the trusses can be erected manually. After the plates are in place, hoist one end of the truss onto one wall with the peak of the roof down. Then hoist the other end of the truss onto the opposite wall. Attach ropes to the peak of the truss so that when it is swung into place, one man on each rope can hold it in an upright position while another man fastens the truss to the poles or cleats at the plates. The truss is then stabilized by nailing 2 x 4 roof purlins to its top side as it is moved into position. With pole type construction, a fastening block, as shown in Fig. 8, is most effective. In frame or masonry construction, the truss should be fastened with sections of angle iron or other positive fasteners. For 50- and 60-foot trusses, a crane may be required since these long trusses bend when carried upside-down.

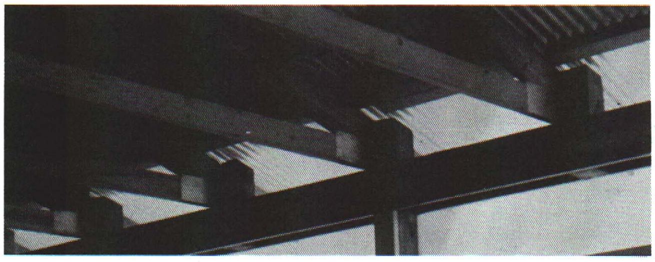


Figure 8 — Truss to rafter-plate joint made with a short 6 in. by 6 in. block.

Selecting Rafter Plates

The size of rafter plates is determined by the span of the truss and spacing of poles. Table 1 shows the size of material and the number of members required for different combinations of span and pole spacing. For example, in a 40-foot wide building with poles spaced 14 feet apart, trusses should be centered 4 feet, 8 in. and two-2 x 10's used on the inside of the pole and one-2 x 12 on the outside of the pole.

The roof load is transferred to the pole by nails or a combination of nails and bolts. Table 2 shows the number of 6 in. ring- or screw-shank nails needed on each pole. These can be located between the truss-to-pole, rafter plate-to-pole, or, if more nailing space is needed, a scab can be applied below the plate as shown in Fig. 9.

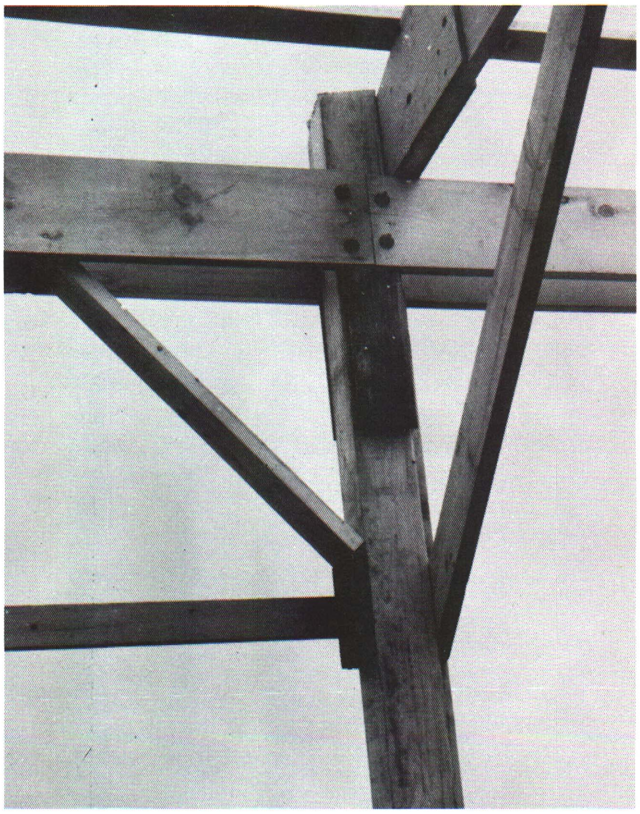


Figure 9 — A well-constructed joint at the pole. Four bolts have been substituted for about one-half of the nails; wind braces in two directions.

Table 1 — Number and Size of Rafter Plates Required For Clear Span Pole Type Buildings

Pole Spacing	Truss Spacing	Width of Building (Ft.)				
		30′	36′	40′	50′	60′
(Ft.)	(Ft.)	(No.)	(No.)	(No.)	(No.)	(No.)
8	4′ 0″	1 — 2 x 6 1 — 2 x 8	2 — 2 x 8	2 — 2 x 8	1 — 2 x 8 1 — 2 x 10	2 — 2 x 10
12	4′ 0″	2 — 2 x 10	1 — 2 x 10 1 — 2 x 12	1 — 2 x 10 1 — 2 x 12	3 — 2 x 12	3 — 2 x 12
14	4′ 8″	1 — 2 x 10 1 — 2 x 12	2 — 2 x 12	2 — 2 x 10 1 — 2 x 12	4 — 2 x 12	
15	3′ 9″	2 — 2 x 10 1 — 2 x 12	1 — 2 x 10 2 — 2 x 12	3 — 2 x 12	*These dimensions not recommended*	
16	4′ 0″	1 — 2 x 10 2 — 2 x 12	3 — 2 x 12			

Plans

The following plans for glue-nailed and ring-bolt trusses are available from County Agricultural Agents or from the Agricultural Engineering Department, Michigan State University: (Figure 10 is a typical plan for a 40-foot glue-nail truss).

703-Cl-56 24′ Ring Bolt Truss - 1/6 Pitch
703-Cl-58 24′ Glue Nail Truss - 1/6 Pitch
703-Cl-60 30′ Ring Bolt Truss - 1/6 Pitch
703-Cl-62 30′ Glue Nail Truss - 1/6 Pitch
703-Cl-64 36′ Ring Bolt Truss - 1/6 Pitch
703-Cl-66 36′ Glue Nail Truss - 1/6 Pitch
703-Cl-68 40′ Ring Bolt Truss - 1/6 Pitch
703-Cl-70 40′ Glue Nail Truss - 1/6 Pitch
703-Cl-74 50′ Glue Nail Truss - 1/6 Pitch
703-Cl-84 24′ Ring Bolt Truss - 1/6 Pitch - Single Slope
703-Cl-85 24′ Glue Nail Truss - 1/6 Pitch - Single Slope
703-Cl-87 30′ Glue Nail Truss - 1/6 Pitch - Single Slope "A"
703-Cl-88 30′ Glue Nail Truss - 1/6 Pitch - Single Slope "B"
703-Cl-89 60′ Glue Nail Truss - 1/6 Pitch
703-Cl-91 40′ Glue Nail Truss - 1/6 Pitch - (to support ceiling loads)

Roofing

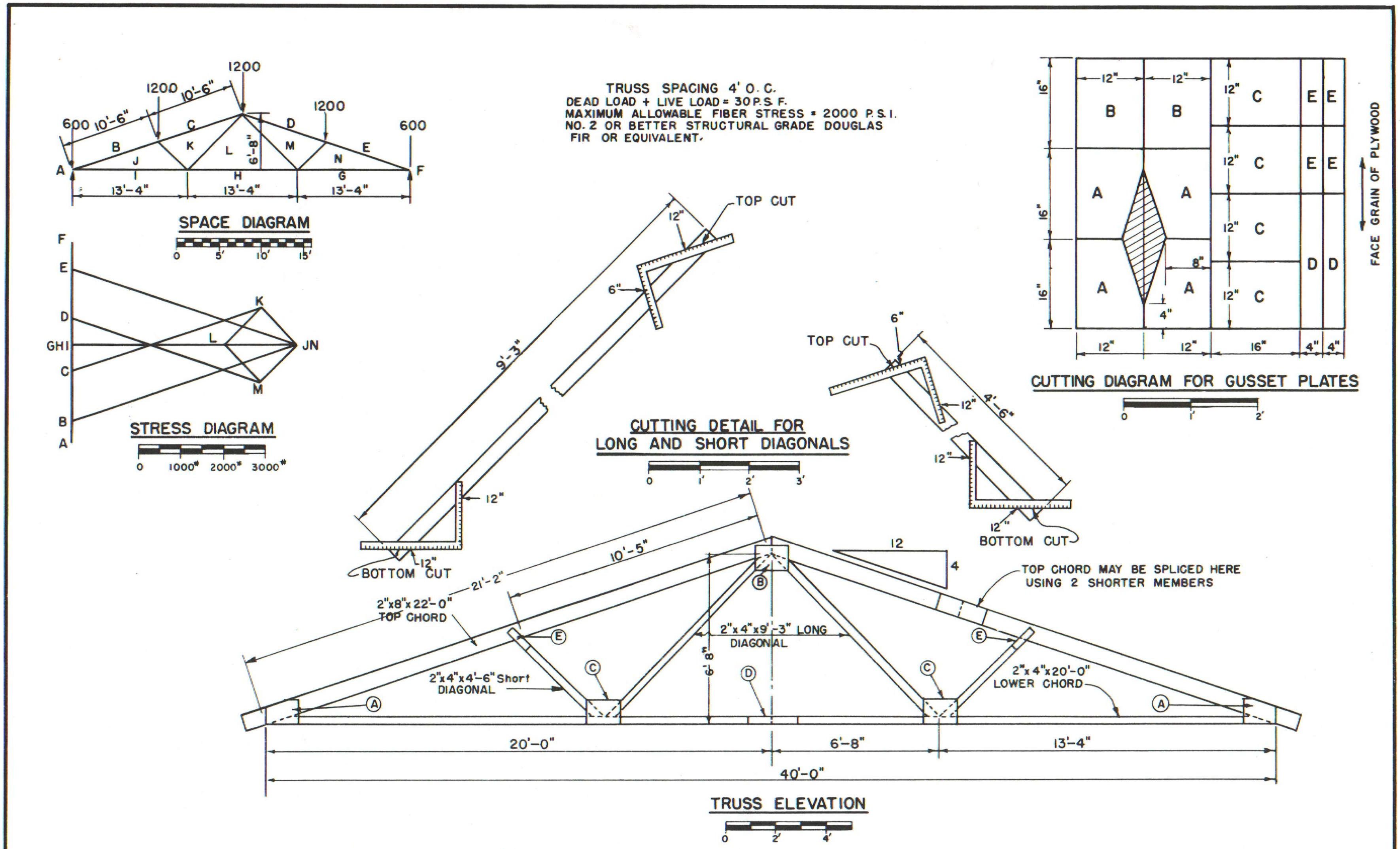
When trusses are spaced 4 ft. apart, 2 x 4 purlins can be laid flatly over the trusses to assure a good connection. Figure 11 shows what happens when only one nail is used to fasten the purlin to the truss. When trusses are spaced more than 4 ft. apart, the stress on the truss-to-purlin joints may be so great that the roof is blown off. (*Both galvanized sheet metal and aluminum of all patterns can be applied to a 2-foot purlin spacing.*)

Table 2 — Number of Six-Inch Ring- or Screw-Shank Nails Required on Each Pole.*

Pole Spacing	Width of Building (Ft.)				
(Ft.)	30′	36′	40′	50′	60′
8	26	31	35	43	51
12	39	46	51	64	77
14	45	55	60	75	
15	48	58	64		
16	52	62			

**One 5/8 in. bolt can be substituted for eight nails in a joint.*

Figure 11 — Poor nailing of roof girts to trusses caused this section of roof to blow off during high wind.



GENERAL SPECIFICATION

1. USE 5/8" EXTERIOR PLYWOOD FOR GUSSET PLATES ON BOTH SIDES OF ALL JOINTS.
2. ALL GUSSET PLATES ARE GLUED AND NAILED IN PLACE.
3. USE CASEIN OR RESORCINOL RESIN GLUE AND 6d BOX NAILS.
4. MIX GLUE ACCORDING TO MANUFACTURERS' SPECIFICATIONS AND APPLY TO BOTH SURFACES TO BE JOINED.
5. ALL TRUSS MEMBERS ARE IN THE SAME PLANE AND ALL JOINTS ARE BUTT JOINTS.
6. TRUSS MEMBERS ARE CUT TO LENGTH AND THE TRUSS IS ASSEMBLED IN A JIG IN A HORIZONTAL POSITION.
7. THE ASSEMBLED TRUSS MAY BE MOVED CAREFULLY FROM THE JIG IMMEDIATELY AFTER THE GUSSET PLATES HAVE BEEN APPLIED.
8. LEAVE TRUSSES STACKED IN A HORIZONTAL POSITION FOR AT LEAST 24 HOURS AFTER ASSEMBLY.
9. TRUSSES MAY BE PLACED ON FRAME WALLS, MASONRY WALLS, OR POLE CONSTRUCTION
10. PROPER ANCHORAGE OF TRUSSES TO WALLS IS IMPORTANT.

STRESS TABLE

MEMBER	SNOW AND DEAD LOAD	WIND LOAD
BJ	-5630	-1620
CK	-4740	+1400
DM	-4740	+1400
EN	-5690	+1620
NG	+5400	-1570
LH	+3600	-900
JI	+5400	-1570
JK	-1270	+1470
KL	+1270	-470
LM	+1270	-470
MN	-1270	+470

LIST OF MATERIALS

MEMBER	NO. PCS.	SIZE	BD. FT.
TOP CHORD	2	2"x8"x22'-0"	59
LOWER CHORD	2	2"x4"x20'-0"	27
LONG DIAGONAL	2	2"x4"x 9'-3"	13
SHORT DIAGONAL	2	2"x4"x 4'-6"	6
			105
6d BOX NAILS	1 LB.		
PLYWOOD GUSSETS	1	5/8"x4'x4'	16 SQ. FT.
CASEIN OR RESORCINOL RESIN GLUE	1 LB		

6-10-64 CKS
1-3-61 CFG
REVISED 9-23-58

MICHIGAN STATE UNIVERSITY
COOPERATIVE EXTENSION SERVICE
AGRICULTURAL ENGINEERING DEPARTMENT, E. LANSING

40' GLUE AND NAIL TRUSS
1/6 PITCH

PLANNED MLE
DRAWN MDS
TRACED
CHECKED MLE
APPR. JSB
SCALE SHOWN
DATE 3-12-56
SHEET 1 OF 1
NO. 703-CI-70

Figure 10 – Typical plan for a 40 ft. glue nail truss.