Investigations of A LOW-COST ROOF for SMALL FARM BUILDINGS

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ON-THE-JOB FABRICATION OF ROOFS for small farm buildings is often costly and time consuming in proportion to the cost of materials. Such roofs take only small amounts of several different materials, but getting and putting them together take considerable time and effort.

The main purpose of this study was to develop a low-cost roof section that could be fabricated in a shop from the 2½-inch corrugated metal sheets commonly used in constructing Illinois farm buildings. The sections were to be designed so that they could be easily and quickly assembled at the site by common labor.

In the design of farm buildings, roofs to withstand loads of 20 to 25 pounds per square foot are frequently used. In the roof sections described here, ordinary 2½-inch corrugated sheets cannot carry these loads without considerable deflection. These roof sections can be used, however, where deflection is of secondary importance.

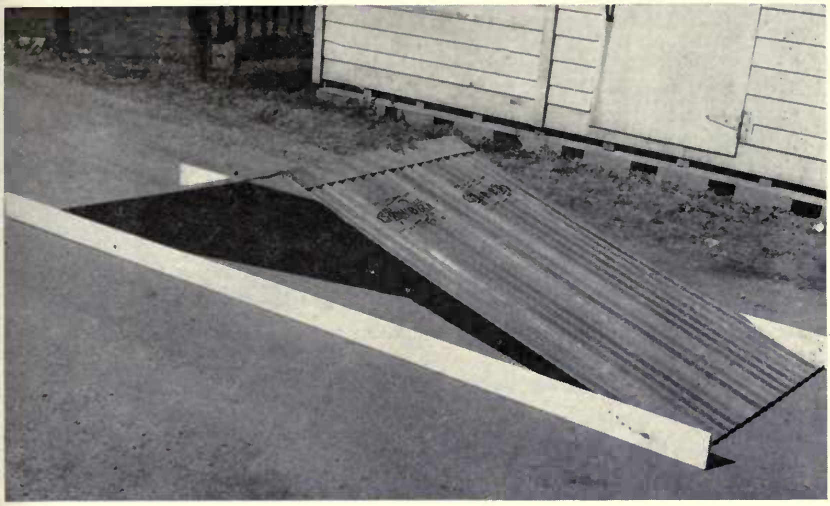
Plan of Tests

To determine minimum requirements for roofs on small farm buildings, six tests were made on lightweight roof sections consisting of only upper and lower chords. Web members usually considered necessary for support and stiffness were omitted. The upper chords were the roofing sheets, and the ties across the bottom formed the lower chords. The ties used were 1 x 6 boards on each side of the roof (Fig. 1). Each section was the width of one sheet of galvanized steel or aluminum roofing. All sheets had 2½-inch corrugations.

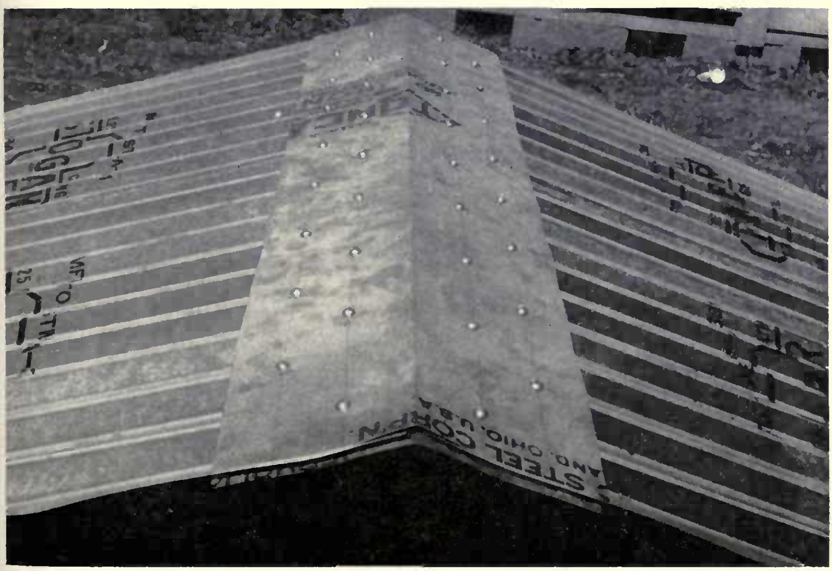
The peak connection was fabricated by bolting or riveting the roofing sheets to flat sheets of the same material (Fig. 2). The flat sheets were formed to the 4:12 slope of the roof. The plate was provided by nailing the roofing sheets to a 2 x 6 member at each side. Two nails were used at each corrugation. Finally, the roof sections were tied with 1 x 6 boards across the bottom (Fig. 3). Sections were of a uniform four-foot width.

To simulate wind and snow conditions, the sections were loaded as uniformly as possible with bricks having an average weight of 4.775 pounds each. Conversion of these loads to snow and wind loads is given in Table 1.

Deflection readings were taken on both edges of the roof section at the quarter points of the span and at the peak (Fig. 4).



Test section, lightweight roof. Each section width of one sheet of galvanized steel or aluminum roofing with 2½-inch corrugations. (Fig. 1)



Peak connection fabricated by bolting or riveting roofing sheets to flat sheets of same material bent to slope of roof. (Fig. 2)

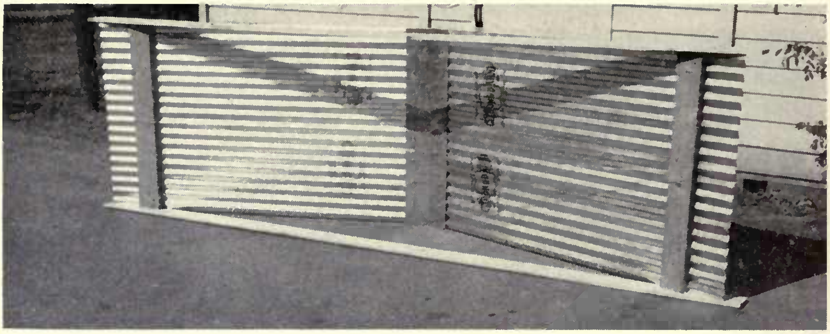
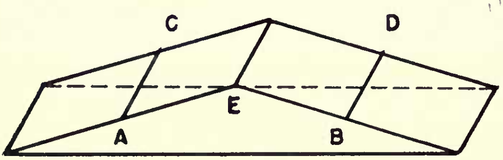


Plate provided by nailing roofing sheets to 2 x 6 member at each side and tying these together with 1 x 6 boards. (Fig. 3)



Deflection readings taken at A, B, C, D, and E. (Fig. 4)

Table 1. — Fresh Snow Equivalent or Wind Velocity Equivalent of Uniform Loads Applied to Roof Sections

Uniform load, pounds per square foot of horizontal projection	Depth of fresh snow,[a] inches to nearest half inch	Wind velocity, miles per hour[b]
5.0	9.0	50
7.5	13.5	62
10.0	18.0	70
10.2	18.5	71
11.9	21.5	76
12.5	22.5	80
15.0	27.5	87
15.9	29.0	88

[a] Weight of fresh snow taken as 6.25 pounds per cubic foot. Depth of snow measured perpendicular to roof.
[b] Based on velocity pressure on roof slope equal to 0.77 q suction; values for height of 30 feet. For height of 20 feet, divide velocity given by 0.95 to obtain equivalent velocity; for 10 feet, use 0.84.

$$q = \frac{\text{Load}}{0.77} = \text{maximum velocity pressure}$$

$$v = \sqrt{\frac{q}{0.00256}} = 10\sqrt{\frac{10\,q}{2.56}} = 19.8\sqrt{q}$$

$$v = 19.8\sqrt{\frac{\text{Load}}{0.77}} = 22.5\sqrt{\text{Load}}$$

Conduct and Results of Tests

Test 1 was made on a steel roof with a 12-foot span, made of 29 gage, 2½-inch corrugated sheets secured at the peak with a ¼-inch bolt at each corrugation. When the average deflection at the quarter points was between 2½ and 3 inches, the roof load was 15.9 pounds per square foot of horizontal projection (Table 2). This weight is equivalent to a fresh snow load of 29 inches.

One side of the roof was then unloaded, while the other side was left at full load (Fig. 5). The deflection of the fully loaded side changed very little, but that of the unloaded side was reduced to about ⅜ inch.

Test 2 was made on an aluminum roof section with a 12-foot span. The sheets were .024 inch thick with 2½-inch corrugations and were fastened at the peak with ¼-inch bolts. The load was applied and the deflections measured as before (Fig. 6).

When the roof deflection averaged 2 inches, the load was 11.9 pounds per square foot of horizontal projection (Table 2), the equivalent of 22 inches of snow. After the load was removed, the roof was found to have taken a permanent set of ⅛ inch.

In Test 3 the span of the aluminum roof was increased to 14 feet. The section was loaded as before and deflections were taken. When the average deflection approached 3 inches, the load was 10.2 pounds per square foot, equivalent to 18 inches of fresh snow. The full load was imposed for 29 hours, and deflections were measured at intervals during that period. In 29 hours the average deflection increased approximately ½ inch (Table 2). After the load was removed, the roof had a permanent set of about ½ inch.

Test 4 was conducted with the 14-foot aluminum span inverted to study the effect of an upward wind load on the roof (Fig. 7). The roof section was loaded as before. When the average deflection reached 2¼ inches, the load was 13.6 pounds per square foot (Table 2). The load was left for 72 hours. During this time, the average deflection increased less than ⅛ inch. After the load was removed, the permanent set was 11/16 inch. Part of this set may have been caused by reversing the permanent sets of the previous loadings.

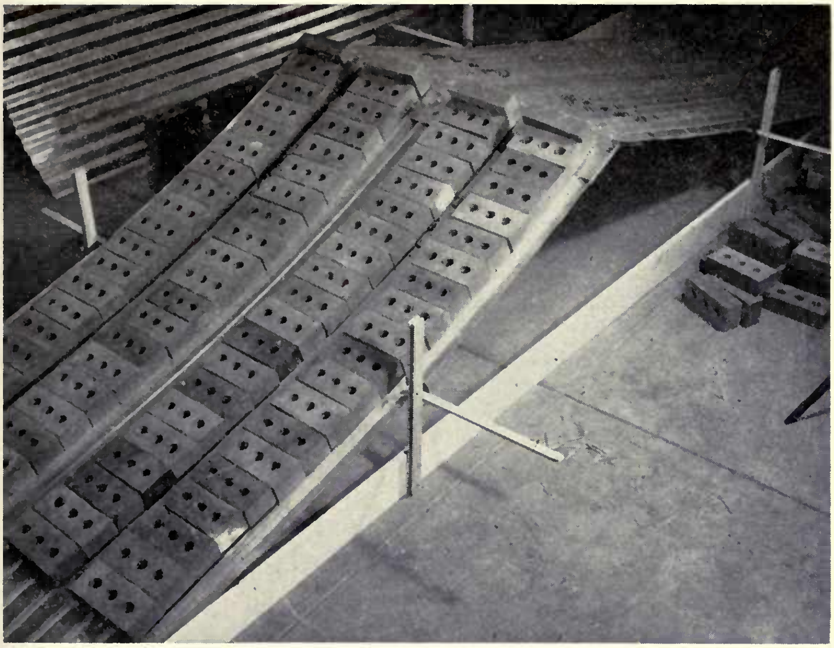
Test 5 was made to try the use of aluminum rivets. The bolts were removed from the peak of the aluminum roof section, and two

Table 2. — Loads and Deflections of Roof Sections; Spans of Varying Widths; Six Tests

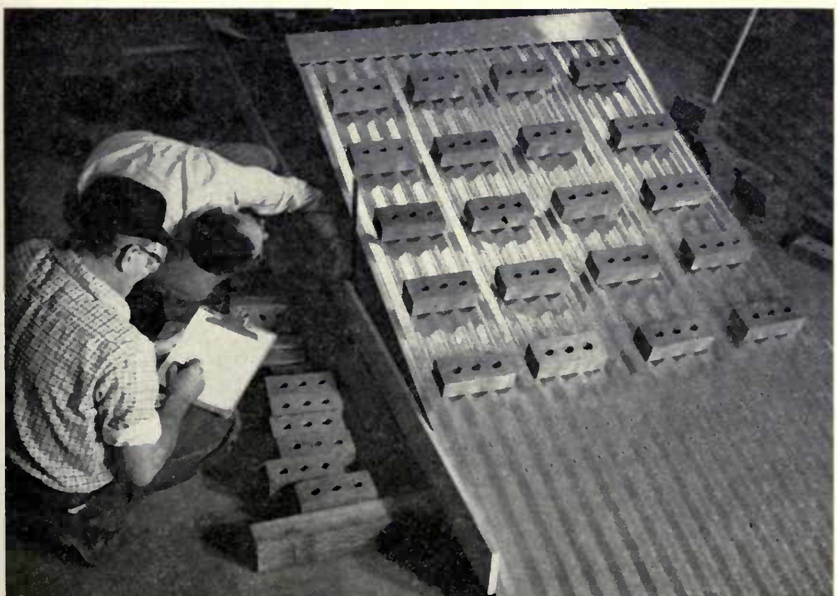
Load — Number of bricks on sides	Pounds per square foot[a]	Deflections at quarter spans and peak, inches — A	B	C	D	E
	Test 1; steel roof section; 12-foot span					
Both sides						
32	6.5	1	1 1/8	15/16	3/4	([b])
60	11.9	2 1/16	2 1/16	1 15/16	1 9/16	1/4
80	15.9	2 7/8	2 3/4	2 1/2	2 1/16	5/8
Each side						
80, left; 40 right	15.9 (l); 7.9 (r)	2 3/4	2 13/16	1 5/8	1 1/4	7/16
80, left; 20 right	15.9 (l); 3.9 (r)	2 11/16	2 13/16	1 1/16	13/16	3/8
80, left; 0 right	15.9 (l); 0 (r)	2 9/16	2 3/4	7/16	3/8	3/16
	Test 2; aluminum roof section; 12-foot span					
Both sides						
20	3.9	11/16	1/2	11/16	3/8	1/8
40	7.9	1 3/8	15/16	1 3/8	3/4	3/8
60	11.9	2 7/16	1 5/8	2 5/16	1 1/2	7/8
0	0	1/8	1/8	1/8	1/8	1/16
	Test 3; aluminum roof section; 14-foot span					
Both sides						
20	3.4	7/8	7/8	1	7/8	
40	6.8	1 11/16	1 11/16	1 13/16	1 5/8	
52	8.8	2 5/8	2 5/8	2 13/16	2 5/8	
60	10.2	2 13/16	2 7/8	3 1/16	2 7/8	
Both sides; measured at given intervals						
60; after 5½ hours	10.2	3 1/16	3 1/8	3 5/16	3 1/8	
60; after 24 hours	10.2	3 3/16	3 5/16	3 1/2	3 3/8	
60; after 29 hours	10.2	3 5/16	3 3/8	3 5/8	3 7/16	
0	0	7/16	1/2	9/16	5/8	
	Test 4; aluminum roof section inverted; 14-foot span					
Both sides						
28	4.7	1 3/16	7/8	1 3/16	1	
40	6.8	1 5/8	1 1/4	1 5/8	1 7/16	
60	10.2	1 15/16	1 11/16	1 7/8	1 3/4	
80	13.6	2 3/8	2 1/8	2 6/16	2 3/16	
80; after 72 hours	13.6	2 3/8	2 1/4	2 3/8	2 1/4	
0	0	13/16	7/16	15/16	9/16	
	Test 5; aluminum roof section; 14-foot span; peak connection formed by one flat sheet with two aluminum rivets at each corrugation					
Both sides						
20	3.4	1 3/8	1 1/4	1 1/4	1	
40	6.8	2 5/8	2 3/8	2 1/2	2 1/4	
52	8.8	4 3/8	4	4 1/4	3 1/2	
52; after 24 hours	8.8	5 5/8	4 3/4	5 1/2	4 1/4	
	Test 6; aluminum roof section; 14-foot span; peak connection formed by two flat sheets with two aluminum rivets at top and bottom of each corrugation					
Both sides						
20	3.4	1 1/8	1 1/8	1 1/8	1	
40	6.8	2 1/4	2 1/8	2 1/8	1 7/8	
52	8.8	3 5/8	3 3/8	3 1/4	2 3/4	

[a] Average weight of a brick was 4.775 pounds; area of horizontal projection was 24 square feet on each side.

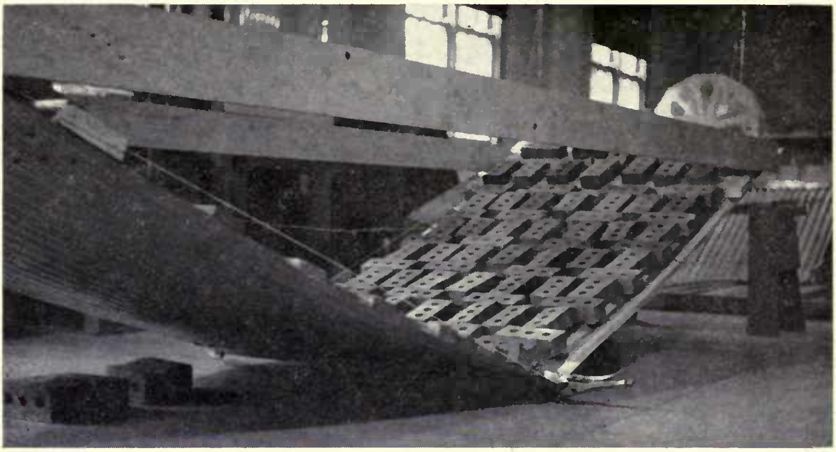
[b] No reading taken.



Steel roof section loaded one side only; 12-foot span. Test 1. (Fig. 5)



Aluminum roof section loaded both sides; 12-foot span. Test 2. (Fig. 6)



Aluminum roof section inverted; designed to simulate wind loads; 14-foot span. Test 4. (Fig. 7)

rivets were put in at each corrugation. The peak connection was formed using a single flat sheet. The span was left at 14 feet and loads were applied as before. The average deflection was approximately 2½ inches at a load of 6.8 pounds per square foot and approximately 4 inches at 8.8 pounds per square foot (Table 2). After 24 hours at the latter load, the deflection increased to over 5 inches, indicating that the joint at the peak did not have adequate rigidity.

Test 6 was made to increase the rigidity of the peak. A second flat sheet was placed on the under side of the peak and fastened with two aluminum rivets at each corrugation. In this test, when the load was 6.8 pounds per square foot, average deflections were approximately 2⅛ inches (Table 2). When the load was increased to 8.8 pounds per square foot, average deflections were 3¼ inches.

The roofs of many small farm buildings are designed to carry established minimum loads that appear to be heavier than necessary. Service and utility buildings are seldom subjected to loads of the magnitude tested, and then usually for only very brief periods, such as come from gusts of wind or an unusual snowfall that soon melts or blows away. Both the steel and aluminum roof sections tested indicate an ability to perform their function satisfactorily without the usual supporting construction. The deflections found are not objectionable so long as performance is acceptable and no permanent detraction from the appearance of the building results.

To make an actual roof weathertight, joining the aluminum sheets with aluminum rivets or the sheet metal sheets with metal screws at about 1-foot intervals with strip caulking applied at the same time would be a good practice. The caulking strip may be offset so that it does not interfere when the holes for screws or rivets are drilled (Fig. 8).

Fabrication

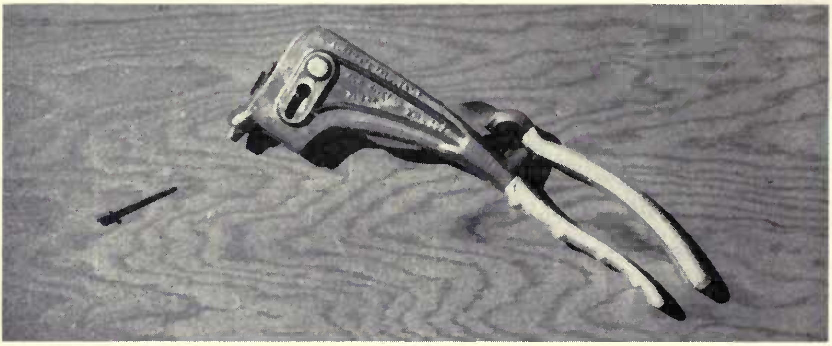
A pliers-type rivet gun (Fig. 9) makes fabrication of an aluminum roof fast and easy. A peak connection can be made by first fastening one plate on the bottom of the sheet, riveting through the valleys, and then securing the top plate by riveting through the top of the corrugations (Fig. 10).

The assembled roof can be set in place on any type of wall or on poles. Methods of connecting the plates are illustrated in Figs. 13 and 14.

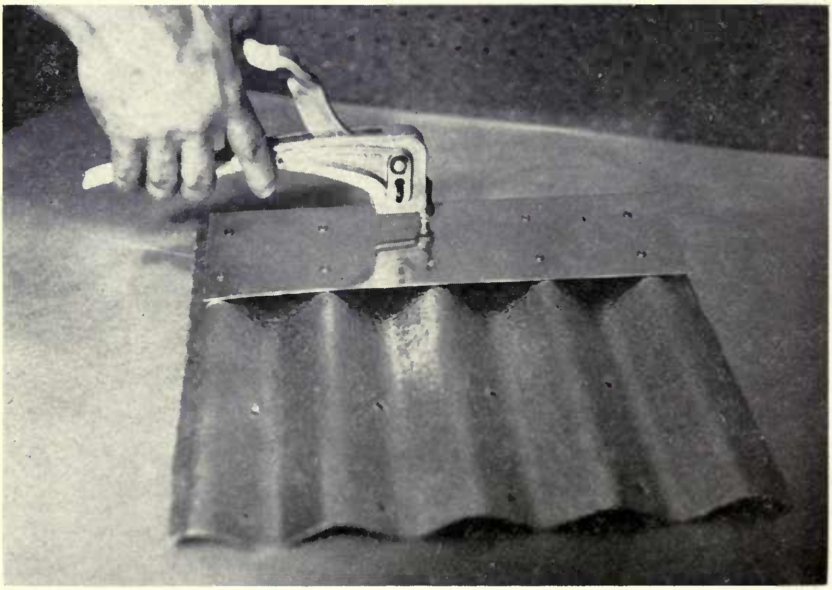
Strip caulking offset at sheet joints from rivet or screw line for weathertight seal. Does not interfere with hole drilling. (Fig. 8)

The use of ties is recommended with all types of wall construction. Tie-to-plate connections can be made with commercially available framing anchors or steel strapping.

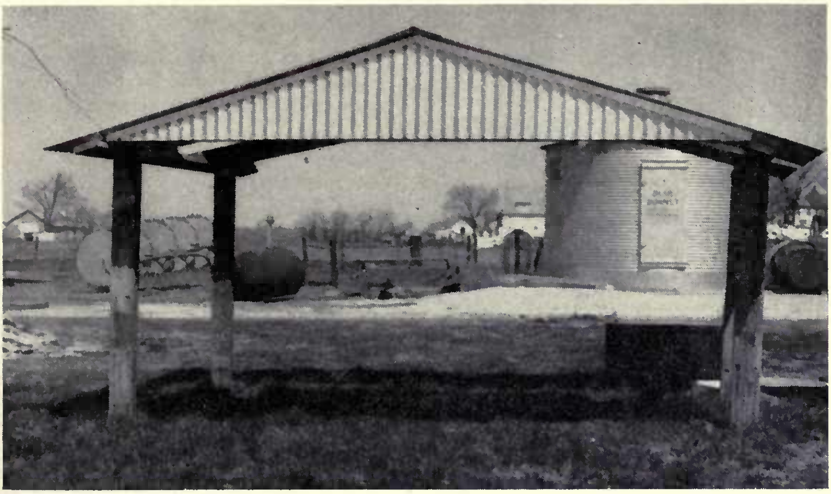
The test sections shown in Fig. 11 withstood the 1959 ice storm, the worst in fifty years. Examination has shown all parts of the sections to be in excellent condition. They show no effect of the excessive load they carried.



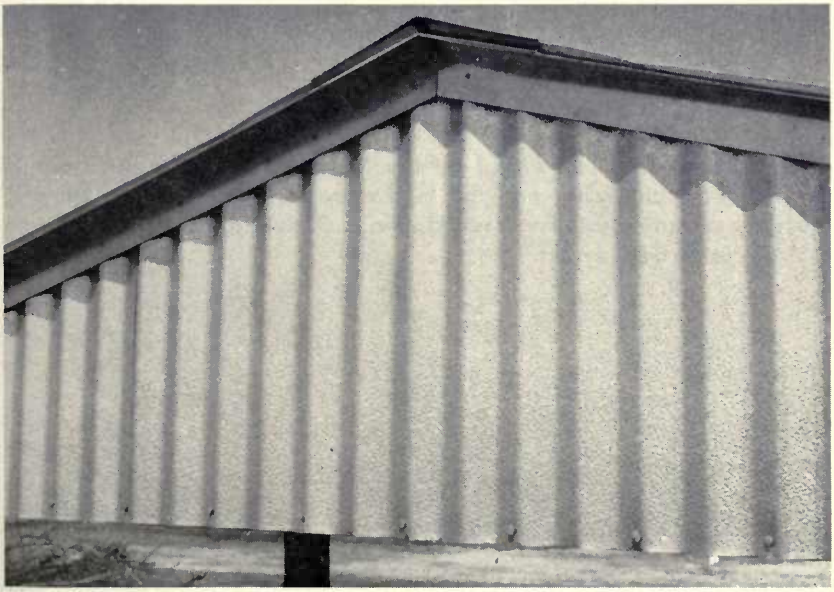
Pliers-type rivet gun for fast and easy fabrication of aluminum roof. (Fig. 9)



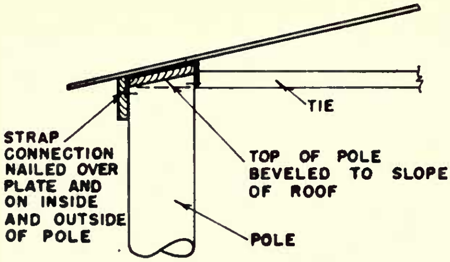
Peak connection formed by first fastening one plate on bottom of sheet, riveting through valleys, then securing top plate by riveting through top of corrugations. (Fig. 10)



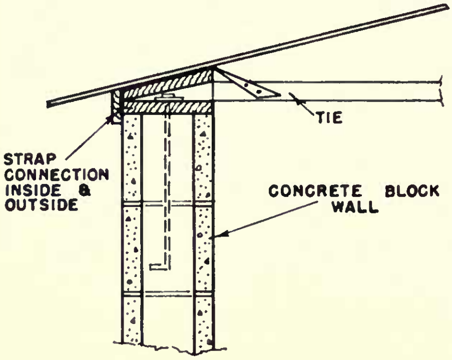
Test roof of lightweight construction used as field shade. This roof withstood the worst ice storm in fifty years without damage. (Fig. 11)



End section formed by riveting flashing or fastening with sheet metal screws. (Fig. 12)



Pole construction with lightweight roof simply made by beveling top of poles to receive plate. (Fig. 13)



Masonry construction requires a second plate on top of wall to withstand uplift. Tie is beveled to roof slope. (Fig. 14)

The roof tests were conducted by the late F. W. Bauling, Assistant in Agricultural Engineering, and the results are reported by E. L. Hansen, Professor of Agricultural Engineering, and E. D. Rodda, Research Associate in Agricultural Engineering.

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