THESIS

DESIGN AND CONSTRUCTION

OF HOWE OR ENGLISH ROOF TRUSS

J. W. MARX A. L. BROWN

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Civil engineering — [illegible]

Design and Construction

of

Howe or English Roof Truss

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J. W. Marx A. L. Brown

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THESIS

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Preface

The problem presented in the following pages shows the method of procedure that was carried out in the design and construction of an "English roof truss", sometimes referred to as an "Howe Roof Truss". The model was built for the purpose of assisting the future instruction in Graphic Statics in the Civil Engineering Department at the Michigan Agricultural College, and perhaps may be found useful in any other work that deals with stresses in truss members.

From a psychological standpoint, a student will more readily understand the principles involved in the construction of a roof truss, if he has the truss itself clearly in mind. It is also hoped by the authors that the model will be of some value to the college and the civil engineering exhibits to suggest to the visitor the scope of at least one branch of the civil engineering curriculum. A model is more attractive to the average individual, that is he can acquire more knowledge in regard to roof trusses in one glance at the model than he could by trying to study a drawing or books.

All the work on the model such as making loop rods for the lower chord, all carpenter work, etc., was performed entirely through our own efforts, thereby turning the work into a practical problem in design and construction.

The authors are very much indebted to Professor H. Z. Vedder for the valuable assistance offered during the course of the work, also to the Mechanical Engineering Department for the use of theshops.

Introduction.

A simple beam may be used for a rafter of a common roof, but when the span of a roof is long it becomes necessary to join several members together and form a truss. A truss is defined as a jointed structure which is arranged to carry loads in such a manner that each principal member is subject to stress only in the direction of its length, that is, to a tensile or a compressive stress. Figure I represents the simplest form of a roof truss.

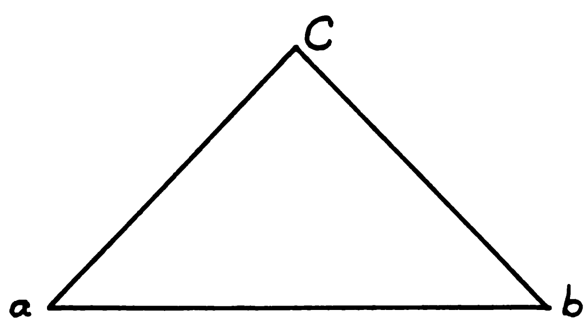


Figure I.

In order that a truss may perfectly conform to the above definition it is necessary that the loads should be supported only at the joints, for flexural stresses will result if they are placed at other points on the members. The elementary figures included between the truss members are triangles, as is noticed in the model, because a triangle cannot change the shape without altering the length of its sides.

Members which are in compression are called "streets", "columns" or "posts" while those which are in tension are called "tees". They are sometimes referred to as "diagonals" and "verticals" in a roof truss. In figure I the upper members a C and C b are in compression and are called "upper chord", while the lower member a b are in tension and are called the "lower chord".

A simple truss is one which is supported at its ends and which under vertical loads brings only vertical pressures on the supports. It must be remembered that in a roof truss design, that all the forces meeting at any joint must be in equilibrium.

Loads on Roof Trusses

There are four kinds of loads to be considered in roof truss design: the weight of the truss itself, the weight of a roof covering, the snow, and the wind. The weight of roof covering and truss is called the "dead load".

For the theoretical weight of the truss, the following empirical formula may be used

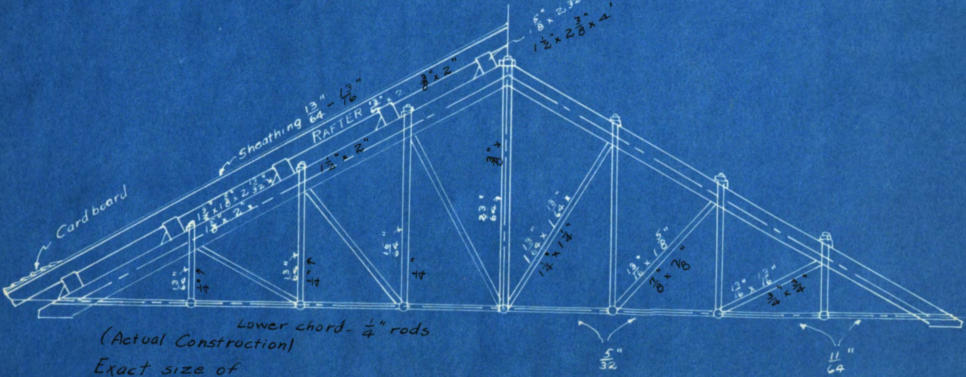
$$W = \frac{3}{4}\, a\, l\, (1 + 1/10\, l)$$

W = approximate weight of one truss in lbs.

l = span in feet

a = distance between trusses

Sketch Showing Exact Scale Reduction of Truss Members



(Actual Construction)
Exact size of
members
shown in black ink.

Conclusion.

Due to our inability to secure the exact sizes of model materials from the college or near-by stores some slight departures had to be made from the intended materials and exact scale reduction. The model should be to one fifth scale and as it stands we think it will serve the purpose adequately as intended.

Below are two sketches showing what the exact sizes of members should be and what we made them.

Design and Construction of a Howe Roof Truss.

Panels---8 10 feet

Rise------20 feet

Span------80 feet

LOADS

Dead Loads

From Ketchums "Steel Mill Buildings", we find that slate of 3/16" thickness is commonly used, the size being 6" x 12". Therefore we will use this size giving a weight of 7.25 lbs. per square foot. Using a 3lap 533 shingles are required for 100 square feet.

Sheathing, purlins and rafters will be made of yellow pine which weights 4 lb. per board foot.

For the weight of the truss a formula from Merrimans "Roofs and Bridges" will be used.

$$W = \tfrac{1}{4} AL\,(I + 1/10\ L).$$

W = the total weight of one truss in pounds.
A = the distance between adjacent trusses in feet.
L = the span of the truss in feet

Materials

The tension verticals and the lower chord shall be of steel. Use an allowable working stress of 1200 lbs. per square inch.
Sheathing and rafters shall be of short leaf yellow pine.
Diagonals, purlins and the upper chord shall be of long leaf yellow pine.
The stresses used shall be those recommended by the A.R.E.A. for buildings. (See Carnegie Handbook, page358.)

Spacing of Trusses

Trusses are not spaced less than 10 feet apart, and for a truss of this span 20 feet can be considered a good spacing. Data collected from "Ketchum's Steel Mill Buildings".

Snow Load

According to Merriman's "Roofs and Bridges" Vol. 1, the maximum snow load for this latitude should be about 22 lbs. per square foot on horizontal projection of roof. The minimum snow load would be about 10 lbs. per square foot on horizontal projection on roof.

Wind Load

For a maximum value use that given by Ducheims, Huttons or the Straight Line formulae.
Parts shall be proportioned for the greatest stress as given by the following combinations.

(1) Dead Load   Maximum Snow Load.
(2) Dead Load   Wind Load   Minimum Snow Load.

Reactions

For the Wind Load the horizontal components of the reactions shall be taken equal.

Note: Tar roofing felt shall be laid between slate and sheathing to assist in making the roof waterproof.

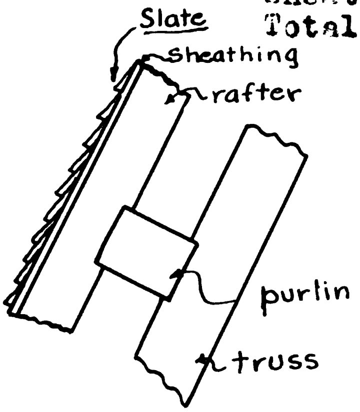
COMPUTATION.

SHEATHING

Assume rafters @ 24" c-c.

Dead Load

Slate @ 7.25 lbs. per square foot.
Sheathing @ 4 lbs. per square foot.
Total = 11.25 lbs. per square foot.



Snow Load (maximum)

$$\frac{20 \times 40}{4.47} = 19.7 \text{ lbs. per sq. ft. (roof surface)}$$

(minimum)

50% of 19.7 = 9.85 lbs. per sq. ft. (roof surface)

Wind Load

$P = .004\ V = .004 \times 6400 = 25.6$ lbs per sq. ft. (vertical surface)

On inclined surface Ducheim = 19 lbs. per sq. ft.
Hutton = 14.8 lbs. per sq. ft.
Straight line = 14.8 " " " "

Note: For V in the formula above a wind velocity of 80 miles per hour is assumed. The value of the wind pressure on inclined surface by the three formulae above is obtained from a graph in Malcolm's "Graphic Statics" on page 74.

Let b = breadth

Total load = 11.25 + 19.7 = 30.97
11.25 + 9.85 + 19 = 40.1
Say 40 lbs.

Assume b = 12"

$$bd^2 = \frac{6M}{f} \qquad (f = 1650)$$

$$d^2 = \frac{6 \times 40 \times 4 \times 12}{8 \times 12 \times 1650} = .0685$$

$$d = .26"$$

Try rafters spaced @ 4 feet c-c.

$$d^2 = \frac{6 \times 40 \times 16 \times 12}{8 \times 12 \times 1650} = .274$$

$$d = .52"$$

USE 1" SHEATHING AND SPACE RAFTERS AT 4 FEET C C.

<u>RAFTERS</u>

Design rafters allowing 1½" notch over purlin.
44.7 feet is the length of roof from point to cornice.

Space purlins $\frac{44.7}{4}$ = 11.2 feet and design rafters accordingly.

Assume a 2" x 8" rafter

Dead Load

2 feet of sheathing on each side of rafter gives
4(7.25 + 4) + wt. of 1 foot of rafter
4(7.25 + 4) + 4.88 = 52.88 lbs. per linear foot.

Snow Load

4 x 17.9 = 71.6 lbs per linear foot. (maximum)
50% of 71.9 = 35.8 lbs. per linear foot (minimum)

Wind Load

4 x 19 = 76 lbs. per linear foot
53   71.6 = 164 lbs. per linear foot

say 164 lbs. per linear foot as total load.

$$bd^2 = \frac{6 \times 164 \times 11.2 \times 12}{8 \times 1650} = 111.8$$

$b = 2$
$d^2 = 55.9$
$d = 7.5"$

7.5"   1.5" = 9"

Try a 2" x 10" rafter

4(7.25 + 4) + 6.64 = 54.6
54.6 + 76.6 + 35.8 = 166.4

say 167 lbs. per linear foot as total load.

$$bd^2 = \frac{6 \times 167 \times 11.2 \times 12}{8 \times 1650} = 113.5$$

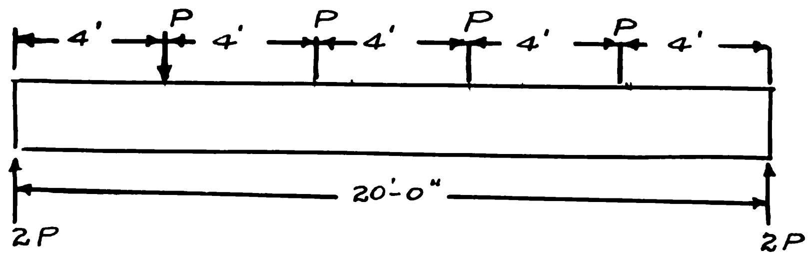
$b = 2"$
$d^2 = 56.7$
$d = 7.52"$

7.52" + 1.5" = 9.02"

<u>USE 2" x 10" for RAFTERS</u>

PURLINS

Design purlins allowing ½" notch over truss.
Span = 20 feet.



P = 166.4 x 112 = 1840

Moment about center of purlin

M = 2P x 10 - 6P - 2P = 12P
M = 12 x 1840 = 22100 ft. lbs.

assume a 6" x 12" for a purlin
weight per foot = 24 lbs.

$\frac{wl^2}{8} = \frac{24 \times 20}{8} = 1200$ lbs.

$\frac{22100 \quad 1200 \times 6 \times 12}{1950 \times 6} = d^2$

d = 12

12 + 1.5 = 13.5"

Try a 8" x 12" timber
weight per foot = 32 lbs.

$\frac{wl^2}{8} = \frac{32 \times 20}{8} = 1600$

$d^2 = \frac{12 \times 6 \times 1600 \quad 22100}{1950 \times 6}$

d = 11.4"

11.4" + .5 = 11.9"

USE 8" x 12" for PURLINS

ESTIMATE OF WEIGHT OF TRUSS.

$w = \frac{1}{4} A L (1 + 1/10L)$

$w = \frac{1}{4} \times 20 \times 80 \left(1 \; \frac{80}{10}\right)$

$w = 800 \times 9 = 7200$ lbs.

Weight per panel = 900 lbs.

LOADS PER PANEL

DEAD LOAD

Weight of slate = 7.25 x 20 x 11.2	=	1625 lbs.
Weight of sheathing = 4 x 20 x 11.2	=	896 lbs.
Weight of rafters = 11.2 x 5 x 6.7	=	375 lbs.
Weight of purlins = 32 x 20	=	640 lbs.
Weight of truss	=	900 lbs.
TOTAL PANEL LOAD	=	4436 lbs.

SNOW LOAD

Maximum = 20 x 10 x 20 = 4000 lbs.

Minimum = 10 x 10 x 20 = 2000 lbs.

WIND LOAD

10 x 11.2 x 20 = 4200 lbs.

REPORT NO. 2

COMPUTATIONS FOR SIZE OF TRUSS MEMBERS.

VERTICALS

1-2 The stress is zero but we will use a 1" upset round bar, with eye at one end to connect to lower chord.

3-4 Max. stress 5490#. $\frac{5490}{12000}$ = .458 sq. in.

Use a 1" upset round bar the same as for vertical 1-2.

5-6 Max. stress 11030#. $\frac{11030}{12000}$ = .922 sq. in.

Use a 1 1/8" upset round bar with eye at one end.

7-8 Max. stress 26160#. $\frac{26160}{12000}$ = 2.18 sq. in.

Use a $1\frac{3}{4}$" upset round bar with eye at one end.
For symmetry the corresponding members on the other half of truss will have the same size members.

UPPER CHORD

Max. stress 69950#. $\frac{P}{A} = 900$

$A = \frac{69950}{900} = 77.7$ sq. in. say 8" x 10".

$\frac{P}{A} = 1950\ (1 - \frac{133}{60 \times 8}) = 1950 \times .724 = 1410$ allowable.

$\frac{7000}{80} = 825$ actual

Assume $\frac{P}{A} = 1200$

$A = 58.2$ say 8" x 8"

$\frac{P}{A} = 1950(1 - \frac{133}{60 \times 8}) = 1410$ allowable

$\frac{69950}{64} = 1090$ actual

Use 8" x 8" plus 2" for notching makes it a 8" x 10".

LOWER CHORD

Max. stress 66060#. Length c-c of eye 120".
$\frac{66060}{12000} = 5.5$ sq. in.
Use 2 loop bars r = .9in. = 7/8"
Members Y1, Y2, Y13, Y14
Members Y4,6,9,11 use ¾" loop bars.
Diameter of pin 1 1/8 "

DIAGONALS 3-2

Max. stress 12600 Length 11' 3"

Assume $\frac{P}{A} = 1200$

$A = \frac{12600}{1200} = 10.5$ sq. in. say 3" x 4".

$\frac{P}{A} = 1950(1 - \frac{135}{60 \times 3}) = 1950 \times .25 = 507$ allowable

$\frac{12600}{12} = 1050$ actual

Assume $\frac{P}{A} = 900$

$A = \frac{12600}{900} = 14$ sq. in. say 4" x 4"

$\frac{P}{A} = 1950 (1 - \frac{135}{60 \times 4}) = 1950 \times .45 = 875$ allowable

$\frac{12600}{16} = 788$ actual Use 4" x 4"

DIAGONAL 4-5

Max. stress 15985 Length 14' 3"

Assume $\frac{P}{A} = 700$

$A = \frac{15985}{700} = 22.8$ sq. in. say 4" x 6"

$\frac{P}{A} = 1950 (1 - \frac{169}{240}) = 575$ allowable

$\frac{15985}{24} = 665$ actual

Assume $\frac{P}{A} = 500$

$A = \frac{15985}{500} = 32$ sq. in. say 4" x 8"

$\frac{P}{A} = 1950 (1 - \frac{169}{240}) 575$

$\frac{15985}{32} = 500$ actual

Use 4" x 8".

DIAGONAL 6-7

Max. stress 20125 Length 18'

Assume $\frac{P}{A} = 600$

$A = \frac{20125}{600} = 33.4$ sq. in. say 6" x 6"

$\frac{P}{A} = 1950 (1 - \frac{216}{60 \times 6}) = 600$ allowable

$\frac{20125}{36} = 555$ actual

ACTUAL WEIGHT OF TRUSS

2 verticals 1" 6' 9"	32 lbs.
2 " 1" 11' 2"	60 "
2 " 1[illegible]" 16' 0"	108 "
2 " 1[illegible]" 20' 9"	338 "
2 diagonals 4" x 8" x 13'[illegible]"	298 "
2 " 4" x 4" x 10'9"	115 "
2 " 6" x 6" x 17'6"	464 "
Upper chord 8" x 10"	2520 "
Lower chord [illegible]" loop bars	128 "
7/8" loop bars	195 "
Splices	4 "
Angle Irons	70 "
Bolts, pins, washers and blocks	175 "
Total weight of truss	4507 lbs.

Theoretical weight = 7200 lbs.

[redacted]

[redacted]

Pocket has:
2 Plans