Supplement to

DESIGN OF PLYWOOD WEBS IN BOX BEAMS

STIFFENERS IN BOX BEAMS AND DETAILS OF DESIGN

Information Reviewed and Reaffirmed
October 1952

This Report is One of a Series
Issued in Cooperation with the
ARMY-NAVY-CIVIL COMMITTEE
on
AIRCRAFT DESIGN CRITERIA
Under the Supervision of the
AERONAUTICAL BOARD

No. 1318-A

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin
In Cooperation with the University of Wisconsin

Supplement to

DESIGN OF PLYWOOD WEBS IN BOX BEAMS

STIFFENERS IN BOX BEAMS AND DETAILS OF DESIGN[1]

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Summary

This supplement was prepared to record additional information concerning details of construction of the stiffeners used in the box beam investigation, "Design of Plywood Webs in Box Beams," Forest Products Laboratory Restricted Mimeograph No. 1318. Details of construction of stiffeners and load and reaction blocks are given. Evidence is presented in this supplement to show that with a given spacing stiffeners which served as both flange spacers and web stiffeners produced the maximum beam strength and stiffness; a built-up stiffener provided 2-1/2 times the glue area of a solid stiffener of the same weight; built-up load and reaction blocks were lighter, more rigid, and were more stable dimensionally than solid blocks; and that, with few exceptions, the beams had adequate stiffeners. No rational method of stiffener design, however, can be suggested without further investigation.

Introduction

This report supplements the information in Forest Products Laboratory Mimeograph No. 1318, "Design of Plywood Webs in Box Beams," with particular reference to web stiffeners. The object of the tests reported therein was to determine the effect of panel dimensions, web thickness, and direction of face grain on the buckling and shearing strengths of box beams. Since all beams were designed for web failure, the flanges and stiffeners were designed so that, in general, the webs failed first.

Design for the stiffeners was empirical since a rational method was not known. Consideration was given to the following items: width of

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[1]This is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

stiffener in contact with the web, bearing area in contact with the flanges, compressive strength and column stiffness, both parallel and perpendicular to the length of the beam. With a few exceptions which will be discussed, the design of the stiffeners appeared to be satisfactory.

The box beams varied from 12 to 18 inches in depth, 4-1/8 to 5-1/2 inches in width, and had webs 1/16 inch to 1/4 inch each in thickness. All beams were loaded at the third points of a 10-foot span. Stiffener spacing varied from 4 to 40 inches.

Details of construction are shown[2] in figures 5 to 12. All parts of the beams were machined to correct size and great care was exercised in fitting, clamping, and gluing of assemblies.

Stiffeners

Four types of stiffeners were used as follows:

(a) A diaphragm type, consisting of a solid rectangular piece of Sitka spruce with the grain direction vertical. The edges of these stiffeners were glued to the webs and the ends were glued to the flanges. Thicknesses varied from 1/4 to 1/2 inch.

(b) A built-up stiffener consisting of four verticals connected in pairs by one or more plywood ties. This type, illustrated in figures 8 to 12, provided approximately 2-1/2 times as much glue area for the same weight as did type (a).

(c) A special solid Sitka spruce stiffener similar to type (a), but cut so as to have almost no contact with the webs. This stiffener is shown in figure 9 and was used on one beam, No. 31, to determine the effect of spacing the flanges without restraining the webs.

(d) A special stiffener, used on beam 32 only, consisting of verticals glued to the outsides of each of the webs. The cross section was rectangular 3/8 inch by 3/4 inch, with the 3/8-inch side glued to the web. The length of these sticks was such that they stiffened the webs between the flanges only, as they did not overlap the flanges.

In addition to the stiffeners, the webs were restrained to some extent by the load and reaction blocks. These blocks were of three kinds, and are detailed in figures 5, 6 and 8. The built-up type, shown in figures 7 to 12 and detailed in figures 7, 8, and 12, was used in all but eight of the 52 beams tested. The tapered portion of the load blocks was designed

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[2] The figures in this supplement are numbered consecutively with those of Report No. 1318.

to reduce stress concentration in the flanges. Figure 6 shows the solid types of load and reaction blocks. Figure 5 shows a special type, with rounded ends bearing on steel plates, designed to eliminate stiffening action. These blocks did not touch the webs.

Results

Web failures in wood box beams occur suddenly. It is usually impossible to determine the primary cause of initial failure. Load tests of box beam frames without webs usually show a different elastic curve from that of the complete beam. Frames alone, loaded at the third points, tend to remain straight and horizontal between the loads and also at the reactions. Between a reaction and the nearest load a reversed curve with a point of inflection is found. A complete beam may or may not have this point of inflection, depending on the relative dimensions of the frame and the webs, but the middle third is always curved. When the web fails, the framework attempts to assume its normal shape at a deflection beyond its ultimate. This may result in many secondary effects, such as tension failure in the compression flange, longitudinal shear failure at the reaction blocks, and ripping of the webs both vertically and along the beam-assembly glue lines. Stiffeners near the point of failure frequently were reduced to debris, but lack of strength in the stiffener may or may not have been the primary cause of failure.

Subsequent to the publication of Mimeograph 1318, several beams with thin flanges were tested. One type of failure observed frequently in these beams was a separation of the web from the flange at a concentrated area where the buckle ridge of an outwardly buckling panel met the flange. The glue and adjacent wood fibers in such failures were subjected to tensile or cleavage forces perpendicular to the glue area and concentrated at the edge of the flange nearer to the neutral axis. This condition may occur at the edge of a stiffener also.

An attempt was made to distinguish the web-stiffening from the flange-spacing effects of the stiffeners. Beams 31 and 33 were nearly identical in all respects except in the design of stiffeners: Those for beam 31 were of solid spruce, 3/8 inch thick (fig. 9), cut back so that they did not touch the webs, while those for beam 33 were the built-up type restraining both webs and flanges. Beam 33 proved to be considerably stiffer and stronger than beam 31. Stiffeners consisting of vertical strips glued to the outside of the webs were used on beam 32, which was otherwise similar to beams 31 and 33. These stiffeners were not satisfactory, for a number of them broke loose before the ultimate load was reached. This ultimate load was less than for beams 31 and 33.

Beam 50 apparently failed because of inadequate stiffener glue area. In this beam, the stiffeners were of the solid diaphragm type and were 3/8 inch thick.

A duplicate of beam 63 failed, probably due to inadequate stiffener glue area. Built-up stiffeners were used in this beam, as shown by figure 12. It is probable that stiffeners of beams 64 and 65 were also inadequate.

The effect of solid blocks and solid reaction blocks glued to flanges and webs compared with the roller type of blocks was investigated in beams 1 to 4. The "A" beams had the roller blocks, while the "B" beams had the rigid type. The "B" beams were, in general, slightly stronger and stiffer than the "A" beams, the difference being greater in the beams with the thinner webs.

Solid load and reaction blocks with grain horizontal are less dimensionally stable under moisture changes than the built-up blocks as shown in figures 8 and 12. Built-up load and reaction blocks were found also to be lighter and more rigid.

One reaction block on beam 56 failed in compression in the lower birch bearing plate shown in figure 8. This plate carried compression perpendicular to the grain and had no true ultimate compressive stress. The average unit stress carried in this beam was, with the exception of beam 45, the highest of any of the beams tested.

Conclusions

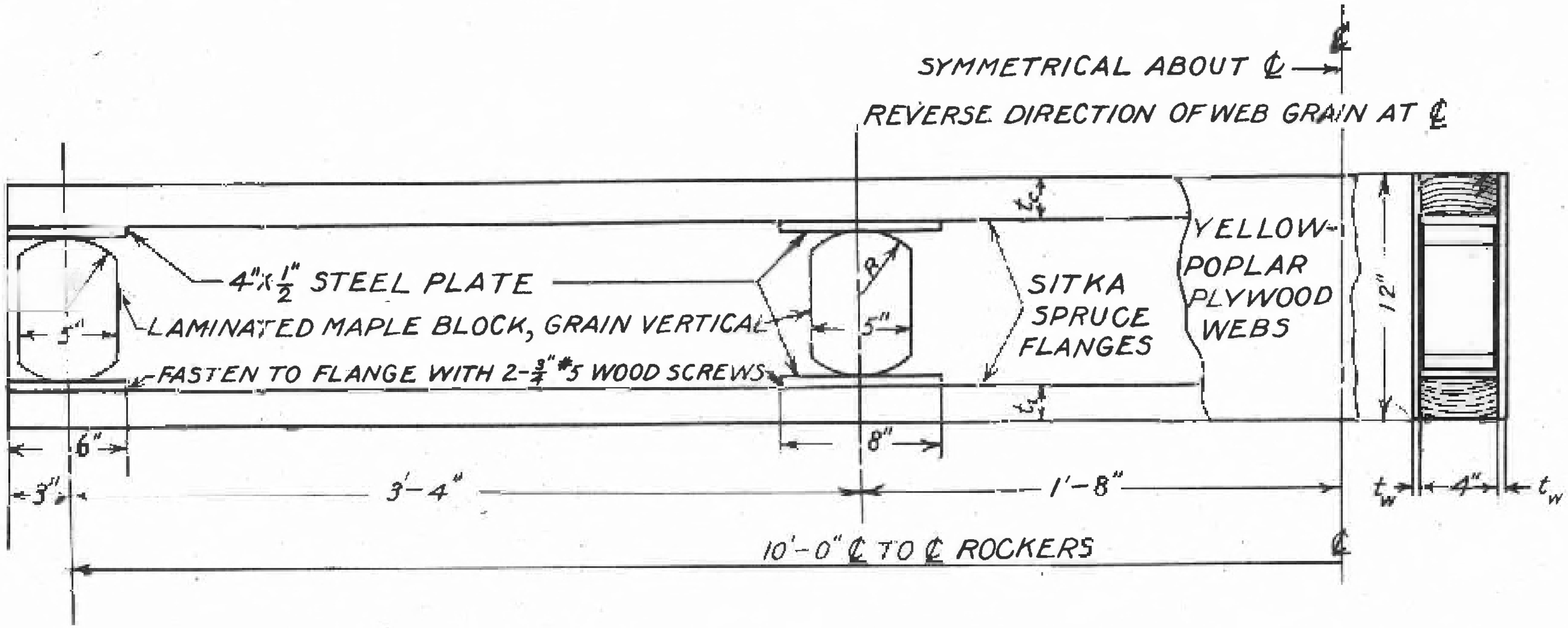
(1) Stiffeners which served as both flange spacers and web stiffeners in wood box beams produced the maximum beam strength and stiffness for a given stiffener spacing.

(2) A built-up stiffener provided 2-1/2 times the glue area of a solid-type stiffener of the same weight.

(3) Built-up load and reaction blocks were lighter, more rigid, and were more stable dimensionally than laminated or solid blocks with the grain direction horizontal.

(4) All beams tested apparently had adequate stiffeners except Nos. 31, 32, 50, and probably 63, 64, and 65. Reaction and load blocks also were adequate except in beam 56.

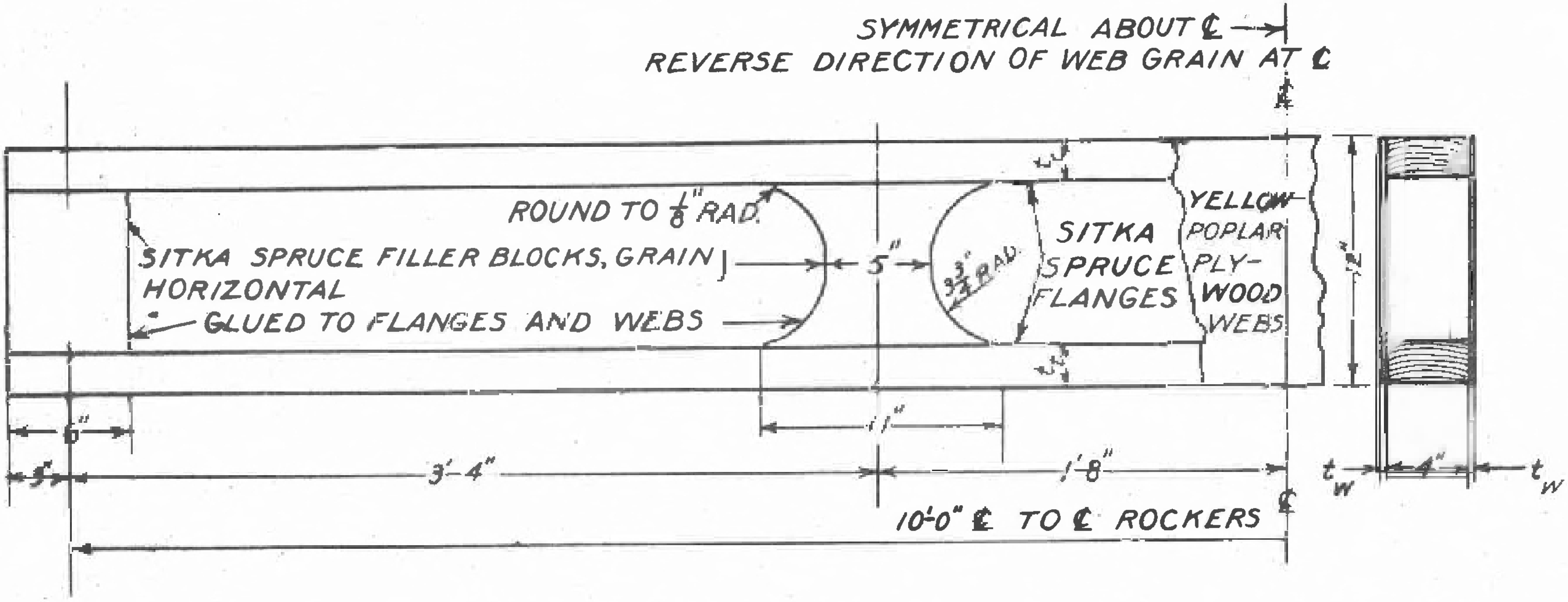
(5) Although several types of stiffeners were used in the box-beam investigation, stiffener design was not a variable in the program. Consequently, the results do not include comprehensive design data for stiffeners. Before a rational design procedure can be established, the internal mechanics of the beam-stiffener combination must be investigated further. The factors to be evaluated include cross-sectional area of the stiffener in terms of both the required column strength and the required bearing area on the flanges, proper width of stiffener at the glue line between it and the web as determined by the grain direction of the face ply of web, and the requirement of preventing a buckle ridge from crossing the stiffeners.



BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	R	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
1A	$2\frac{1}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}" + \frac{1}{8}" + \frac{1}{16}" = \frac{1}{4}"$	$3\frac{1}{4}$"	DOWNWARD
2A	$1\frac{3}{8}$"	$1\frac{3}{8}$"	$\frac{1}{32}" + \frac{1}{16}" + \frac{1}{32}" = \frac{1}{8}"$	$4\frac{1}{8}$"	DOWNWARD
3A	$1\frac{3}{8}$"	$1\frac{3}{8}$"	$\frac{1}{32}" + \frac{1}{16}" + \frac{1}{32}" = \frac{1}{8}"$	$4\frac{1}{8}$"	UPWARD
4A	1"	1"	$\frac{1}{48}" + \frac{1}{24}" + \frac{1}{48}" = \frac{1}{12}"$	$4\frac{1}{2}$"	DOWNWARD

Z M 47667 F

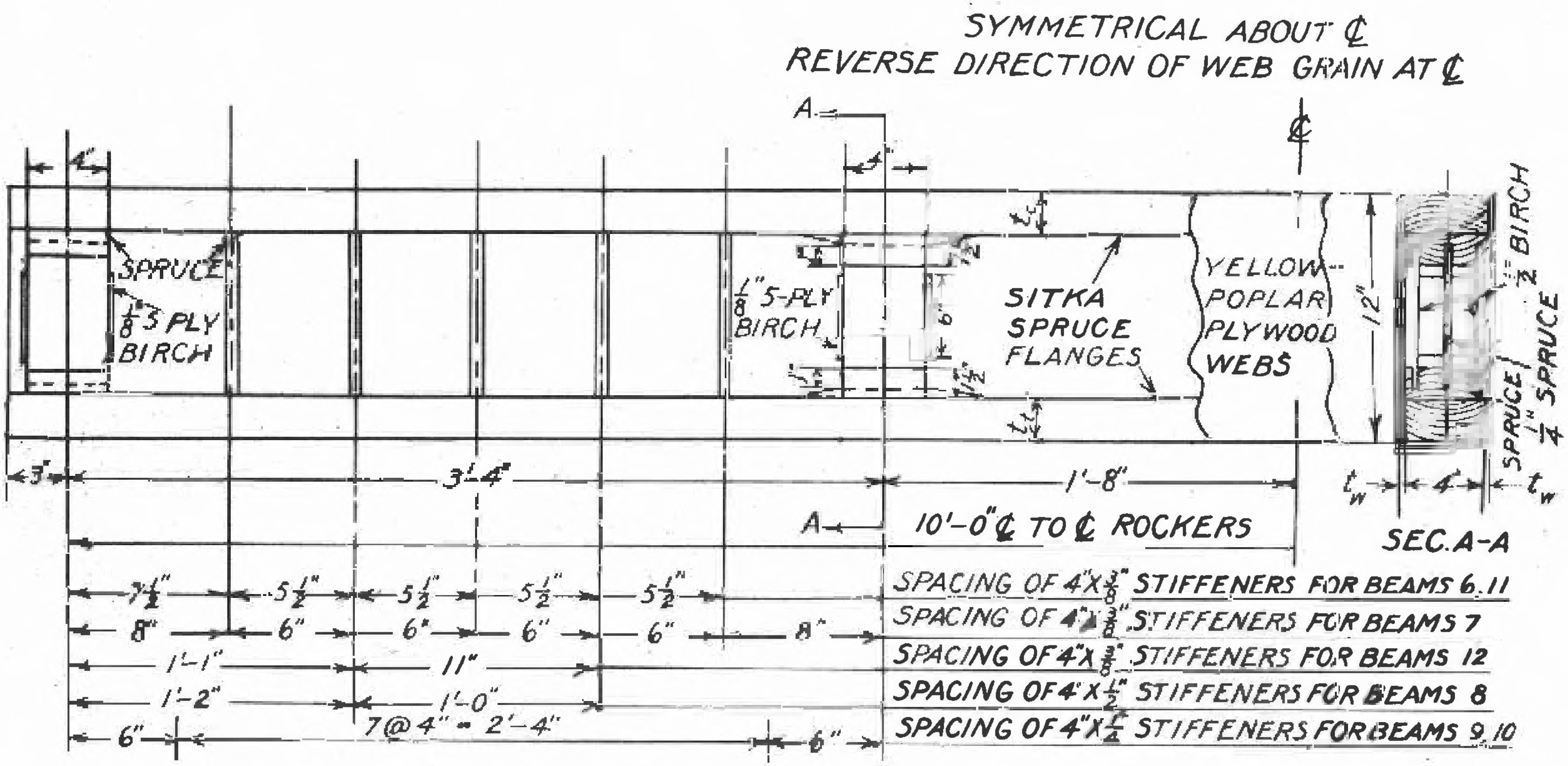
Figure 5.--Details of box beams 1A to 4A.



BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
1B	2 1/4"	2 1/4"	1/16" + 1/8" + 1/16" = 1/4"	DOWNWARD
2B	1 3/8"	1 3/8"	1/32" + 1/16" + 1/32" = 1/8"	DOWNWARD.
3B	1 3/8"	1 3/8"	1/32" + 1/16" + 1/32" = 1/8"	UPWARD
4B	1"	1"	1/48" + 1/24" + 1/48" = 1/12"	DOWNWARD

Z M 47665 F

Figure 6.--Details of box beams 1B to 4B.

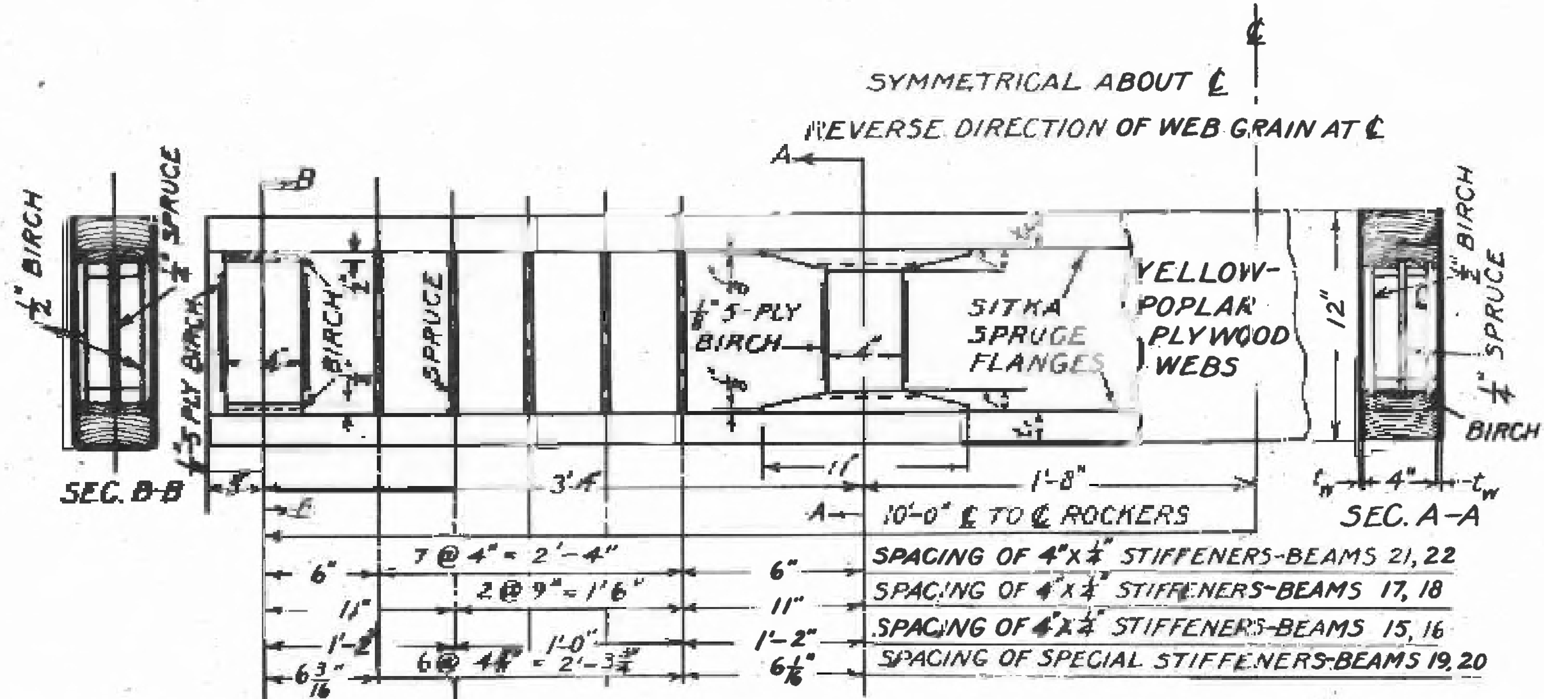


BEAM 5 HAD NO STIFFENERS

BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
5	$2\frac{3}{4}$"	$1\frac{3}{4}$"	$\frac{1}{24}+\frac{1}{24}+\frac{1}{24}+\frac{1}{24}=\frac{1}{6}$"	DOWNWARD
6	$1\frac{3}{4}$"	1"	$\frac{1}{32}+\frac{1}{16}+\frac{1}{32}=\frac{1}{8}$"	DOWNWARD
7	$1\frac{3}{4}$"	1"	$\frac{1}{32}+\frac{1}{16}+\frac{1}{32}=\frac{1}{8}$"	UPWARD
8	$1\frac{3}{4}$"	1"	$\frac{1}{32}+\frac{1}{16}+\frac{1}{32}=\frac{1}{8}$"	UPWARD
9	$1\frac{3}{4}$"	1"	$\frac{1}{32}+\frac{1}{16}+\frac{1}{32}=\frac{1}{8}$"	UPWARD
10	$1\frac{3}{4}$"	1"	$\frac{1}{32}+\frac{1}{32}+\frac{1}{32}+\frac{1}{32}=\frac{1}{8}$"	DOWNWARD
11	$1\frac{1}{4}$"	$\frac{3}{4}$	$\frac{1}{48}+\frac{1}{24}+\frac{1}{48}=\frac{1}{12}$"	UPWARD
12	$1\frac{1}{4}$"	$\frac{3}{4}$"	$\frac{1}{48}+\frac{1}{24}+\frac{1}{48}=\frac{1}{12}$"	UPWARD

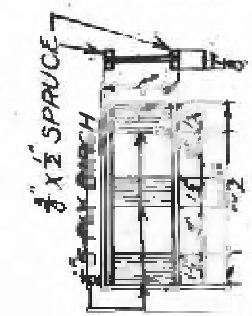
Z M 47663 F

Figure 7.--Details of box beams 5 to 12.



BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
13	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	UPWARD
14	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	DOWNWARD
15	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	UPWARD
16	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	DOWNWARD
17	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	UPWARD
18	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	DOWNWARD
19	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	UPWARD
20	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	DOWNWARD
21	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	UPWARD
22	7/8"	5/8"	1/64" + 1/32" + 1/64" = 1/16"	DOWNWARD

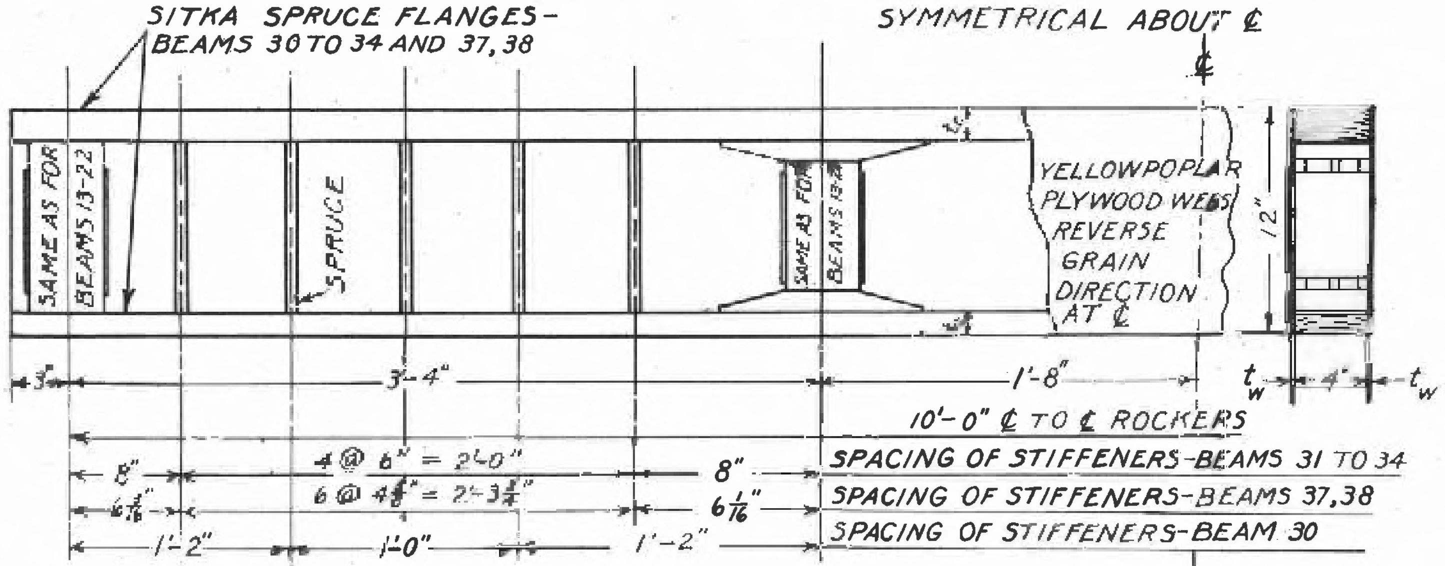
BEAMS 13 AND 14 HAD NO STIFFENERS



STIFFENER FOR BEAMS 19 AND 20 ONLY

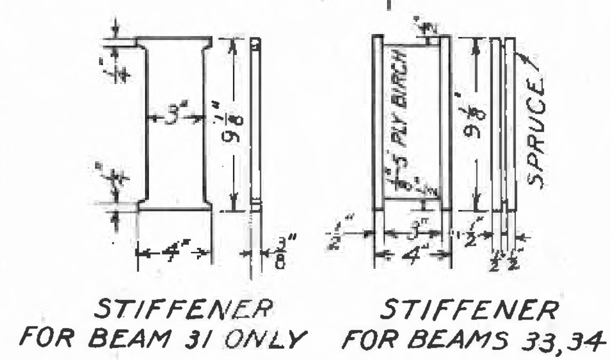
Z M 47662 F

Figure 8.--Details of box beams 13 to 22.



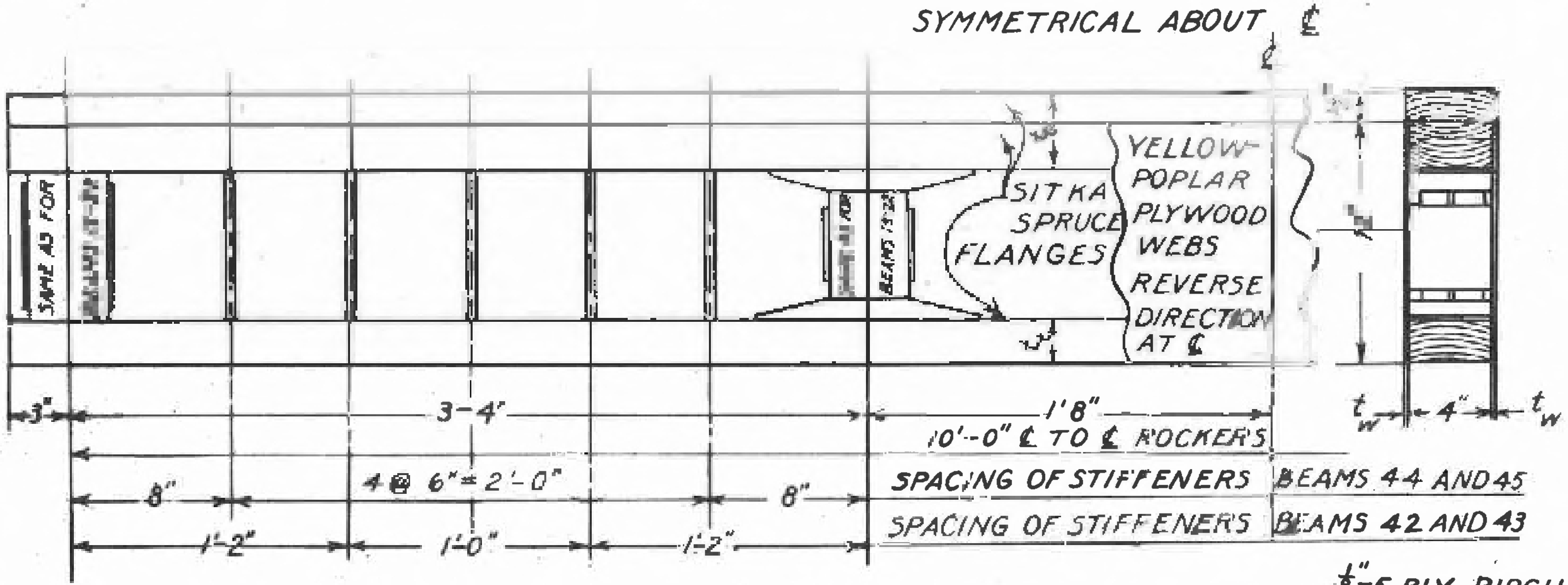
STIFFENERS FOR BEAM 30 WERE 4" x $\frac{3}{8}$"
BEAM 32 HAD $\frac{3}{8}$" x $\frac{3}{4}$" x $9\frac{1}{8}$" STIFFENERS GLUED TO THE OUTSIDE OF THE WEB WITH $\frac{3}{8}$" FACE IN CONTACT.
BEAMS 35 TO 38 HAD STIFFENERS SAME AS FOR BEAMS 19 AND 20

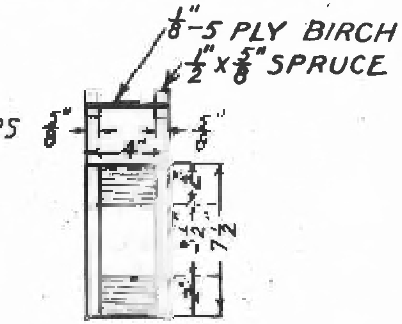
BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
30	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	DOWNWARD
31	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	UPWARD
32	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	UPWARD
33	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	UPWARD
34	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	DOWNWARD
37	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	UPWARD
38	$1\frac{3}{4}$"	$1\frac{1}{8}$"	$\frac{1}{32}$"+$\frac{1}{16}$"+$\frac{1}{32}$"=$\frac{1}{8}$"	DOWNWARD



Z M 47660 F

Figure 9.--Details of box beams 30 to 34, 37 and 38.



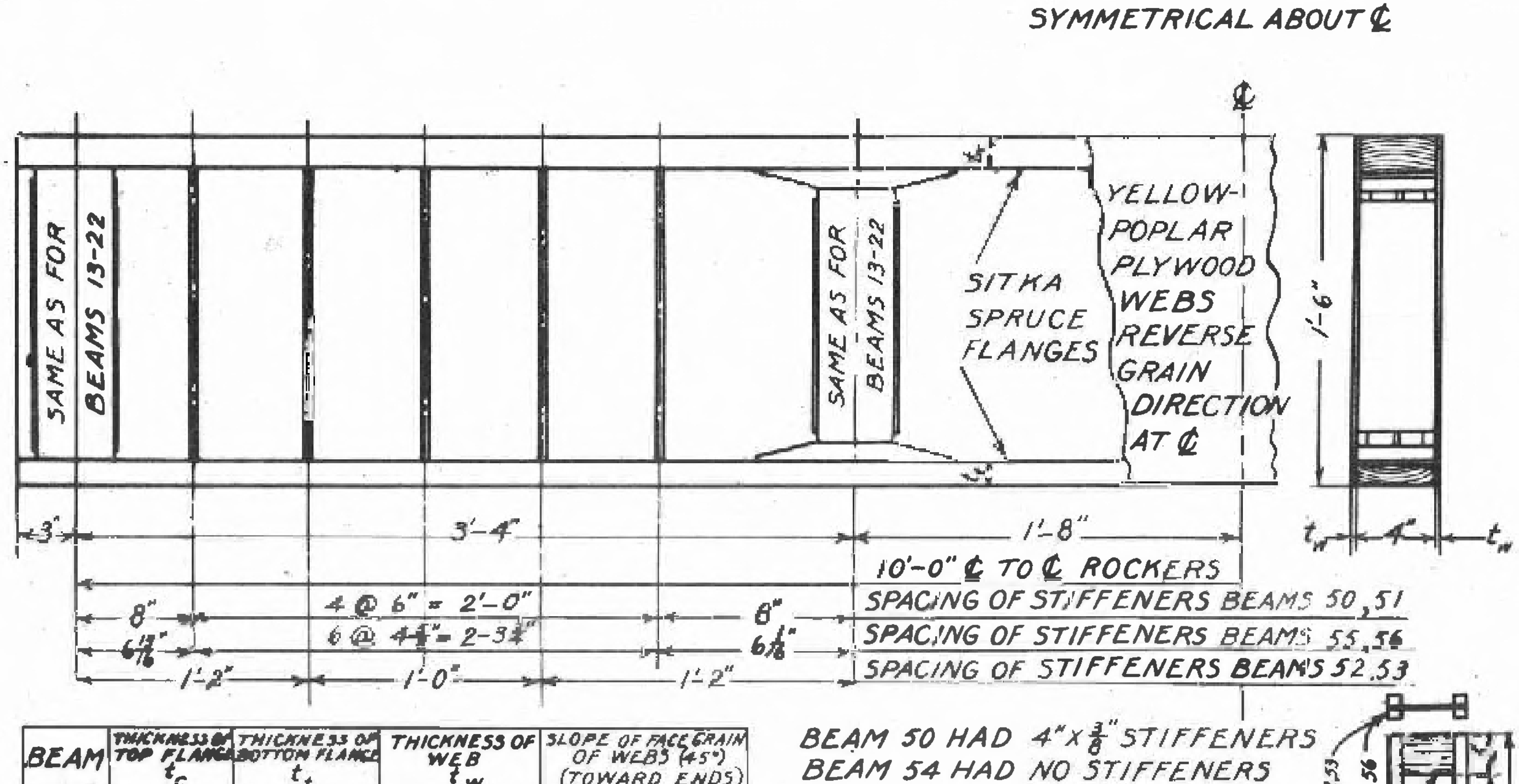


BEAMS 40 AND 41 HAD NO STIFFENERS

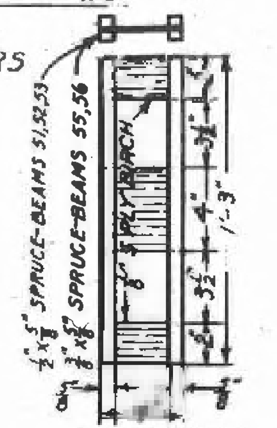
BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
40	$3\frac{3}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	DOWNWARD
41	$3\frac{3}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	UPWARD
42	$3\frac{3}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	DOWNWARD
43	$3\frac{3}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	UPWARD
44	$3\frac{3}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	UPWARD
45	$3\frac{3}{4}$"	$2\frac{1}{4}$"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	DOWNWARD

Z M 47661 F

Figure 10.--Details of box beams 40 to 45.



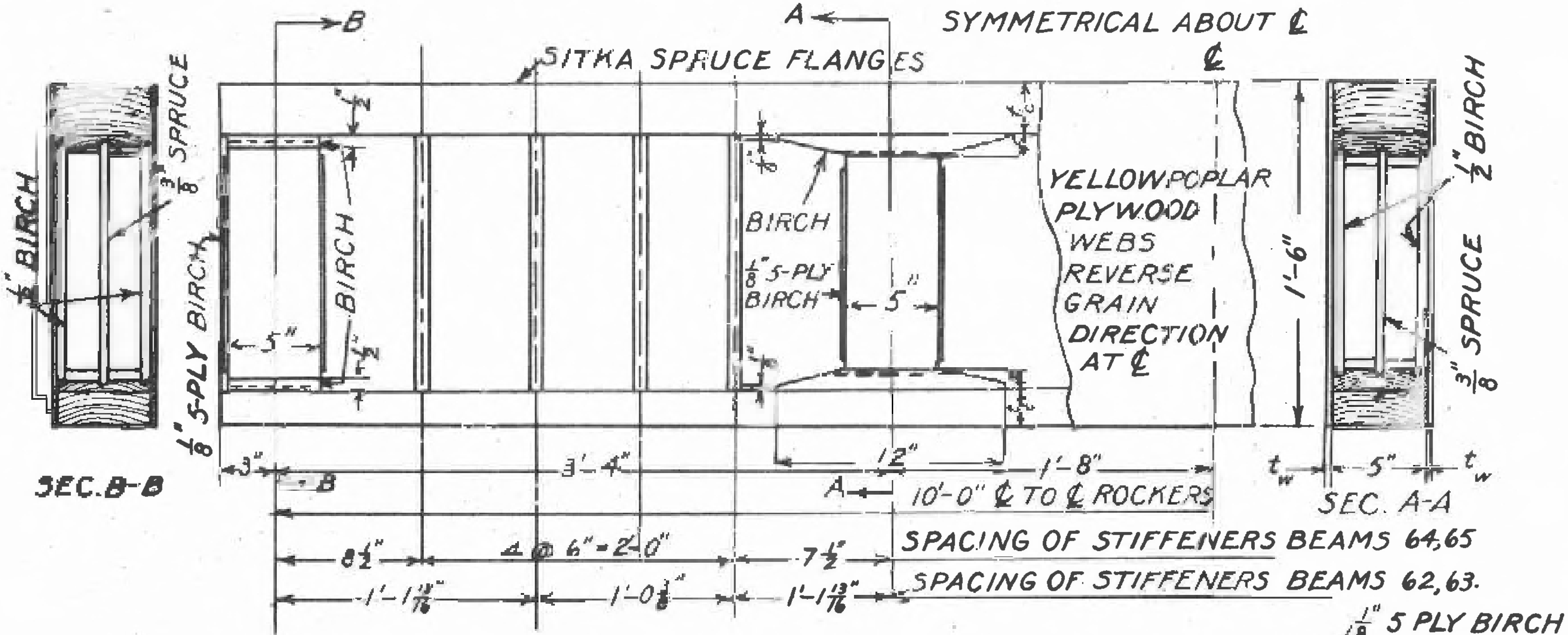
BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
50	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{32}''+\frac{1}{16}''+\frac{1}{32}''=\frac{1}{8}''$	DOWNWARD
51	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{32}''+\frac{1}{16}''+\frac{1}{32}''=\frac{1}{8}''$	UPWARD
52	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{32}''+\frac{1}{16}''+\frac{1}{32}''=\frac{1}{8}''$	UPWARD
53	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{32}''+\frac{1}{16}''+\frac{1}{32}''=\frac{1}{8}''$	DOWNWARD
54	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{32}''+\frac{1}{16}''+\frac{1}{32}''=\frac{1}{8}''$	DOWNWARD
55	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{32}''+\frac{1}{16}''+\frac{1}{32}''=\frac{1}{8}''$	DOWNWARD
56	$1\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{16}''+\frac{1}{16}''+\frac{1}{16}''=\frac{3}{16}''$	DOWNWARD

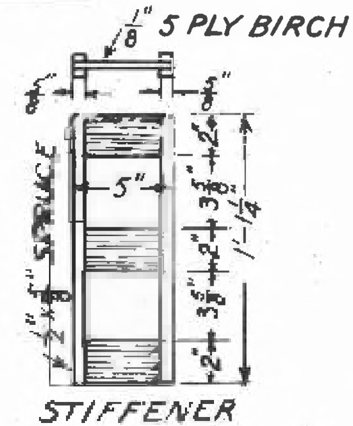


STIFFENER
BEAMS 51, 52, 53, 55, 56

Z M 47666 F

Figure 11.--Details of box beams 50 to 56.





BEAM	THICKNESS OF TOP FLANGE t_c	THICKNESS OF BOTTOM FLANGE t_t	THICKNESS OF WEB t_w	SLOPE OF FACE GRAIN OF WEBS (45°) (TOWARD ENDS)
60	$2\frac{3}{4}$"	2"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	DOWNWARD
61	$2\frac{3}{4}$"	2"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	UPWARD
62	$2\frac{3}{4}$"	2"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	UPWARD
63	$2\frac{3}{4}$"	2"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	DOWNWARD
64	$2\frac{3}{4}$"	2"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	UPWARD
65	$2\frac{3}{4}$"	2"	$\frac{1}{16}"+\frac{1}{8}"+\frac{1}{16}"=\frac{1}{4}"$	DOWNWARD

Z M 47664 F

Figure 12.--Details of box beams 60 to 65.