SIMPLIFIED DESIGN PROCEDURE FOR GLUED-LAMINATED BRIDGE DECKS

USDA FOREST SERVICE
RESEARCH PAPER
FPL 233
1974

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WIS.

ABSTRACT

Procedures have recently been developed for the design of glued-laminated bridge decks and for steel dowel connectors. However, since most bridges are designed in accordance with the Specifications of the American Association of State Highway Officials (AASHO), which consider only three different distributions of wheel load, the original design curves have been reduced here to even simpler equation form.

Equations can be used when designing decks for AASHO H10, H15, and H20 trucks. These equations make it easy and fast for the bridge designer to compute moments and shears in glued-laminated decks.

SIMPLIFIED DESIGN PROCEDURE FOR GLUED-LAMINATED BRIDGE DECKS

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INTRODUCTION

The latest innovation in timber bridge design is the glued-laminated panel deck. Typically, such a deck consists of vertically laminated panels, up to 4 feet in width, which are placed transversely to the bridge stringers. Continuity between the individual panels can be provided by steel dowel connectors. The performance of this system is superior to that of the conventional nail-laminated deck, which has been used for many years.

Procedures for the design of glued-laminated transverse decks and for steel dowel connectors have recently been developed.[2] A computer program was written to analyze a glued-laminated deck as an orthotropic plate, and a series of graphs and tables prepared for computing shears and bending moments for a wide range of design possibilities.

Most bridges are designed in accordance with the "Standard Specifications for Highway Bridges" as adopted by the American Association of State Highway Officials (AASHO). Since these specifications consider only three different distributions of wheel loads, the original design curves can be reduced to equation form.

EQUATIONS FOR DECK DESIGN

The AASHO Standard H10, H15, and H20 trucks are considered to have tire widths (a) of 10, 15, and 20 inches, respectively. In all three cases the tire contact length (b) is taken as 15 inches. Thus, the three AASHO truck classes have tire contact length/width (b/a) ratios of 1.5, 1.0, and 0.75.

Equations which define the deck shears and moments for the AASHO truck classes have been derived from the curves presented in the original report.[2] The figures in the present paper were plotted by selecting values of deck span (s), computing the tire width/span ratio (a/s), and using the appropriate b/a curve to determine the shear or moment coefficient. The coefficient was then plotted against the span.

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[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2]McCutcheon, William J., and Tuomi, Roger L. Procedure for Design of Glued-Laminated Orthotropic Bridge Decks. USDA Forest Serv. Res. Pap. FPL 210. Forest Products Lab., Madison, Wis. 1973.

Figure 1 shows the curves thus obtained for M_x, the primary moment (inch-pound per inch). The equation defining these curves[3] is

$$M_x = P[(0.51 \log s) - K]$$

where P = wheel load (pound) for H10, H15, or H20, and

K = 0.44 for H10
0.47 for H15
0.51 for H20

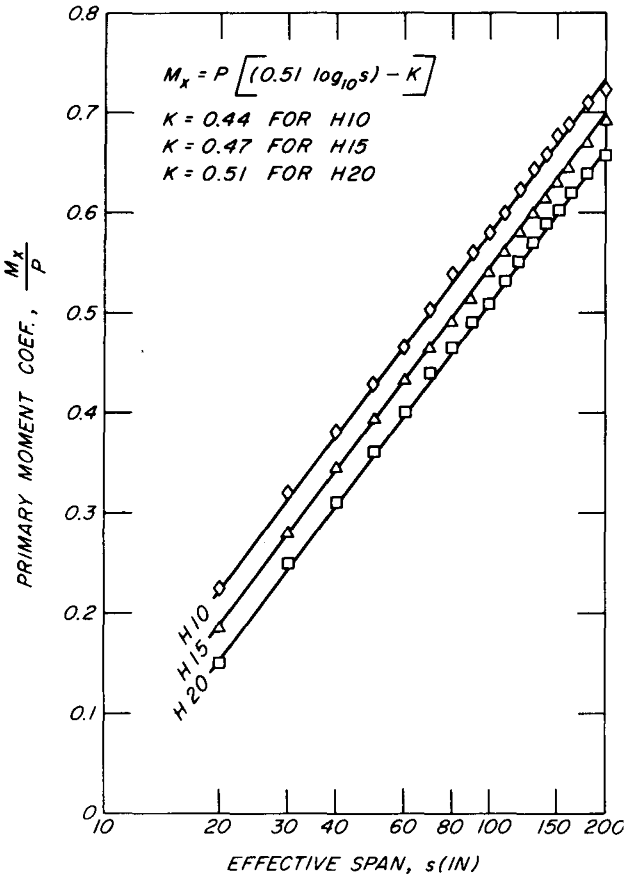


Figure 1.—Primary moment coefficients for ASSHO truck classes M 142 112

Similarly, figure 2 presents the curve obtained for primary shear, R_x (pound per inch). In plotting this figure for the longer deck spans, the edge of the wheel load was assumed to be 15 inches from the support. For short spans, where ½ (s - a) < 15, the load was assumed to be centered between the supports. The effective span, s, is defined in the AASHO specifications. The equation for primary shear, which includes all three truck classes, is

$$R_x = 0.034P$$

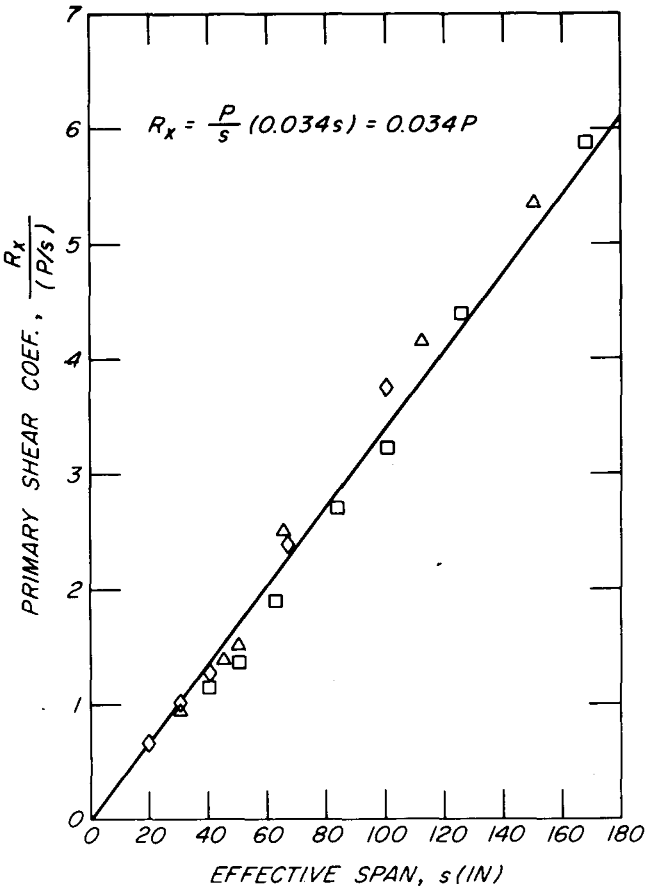


Figure 2.—Primary shear coefficients M 142 113

The plot for secondary moment (for moment in the direction perpendicular to grain), M_y, is shown in figure 3. The equation for this curve is

$$M_y = P[(0.10 \log s) - 0.126]$$

Similarly, figure 4 shows the plot for secondary, or rolling, shear, R_y. The equations for these curves are

$$R_y = \frac{P}{s}(0.017\,s - 0.10) \text{ for H10}$$
$$= \frac{P}{s}(0.015\,s - 0.12) \text{ for H15}$$
$$= \frac{P}{s}(0.013\,s - 0.10) \text{ for H20}$$

[3] ***All** logarithms are base 10.*

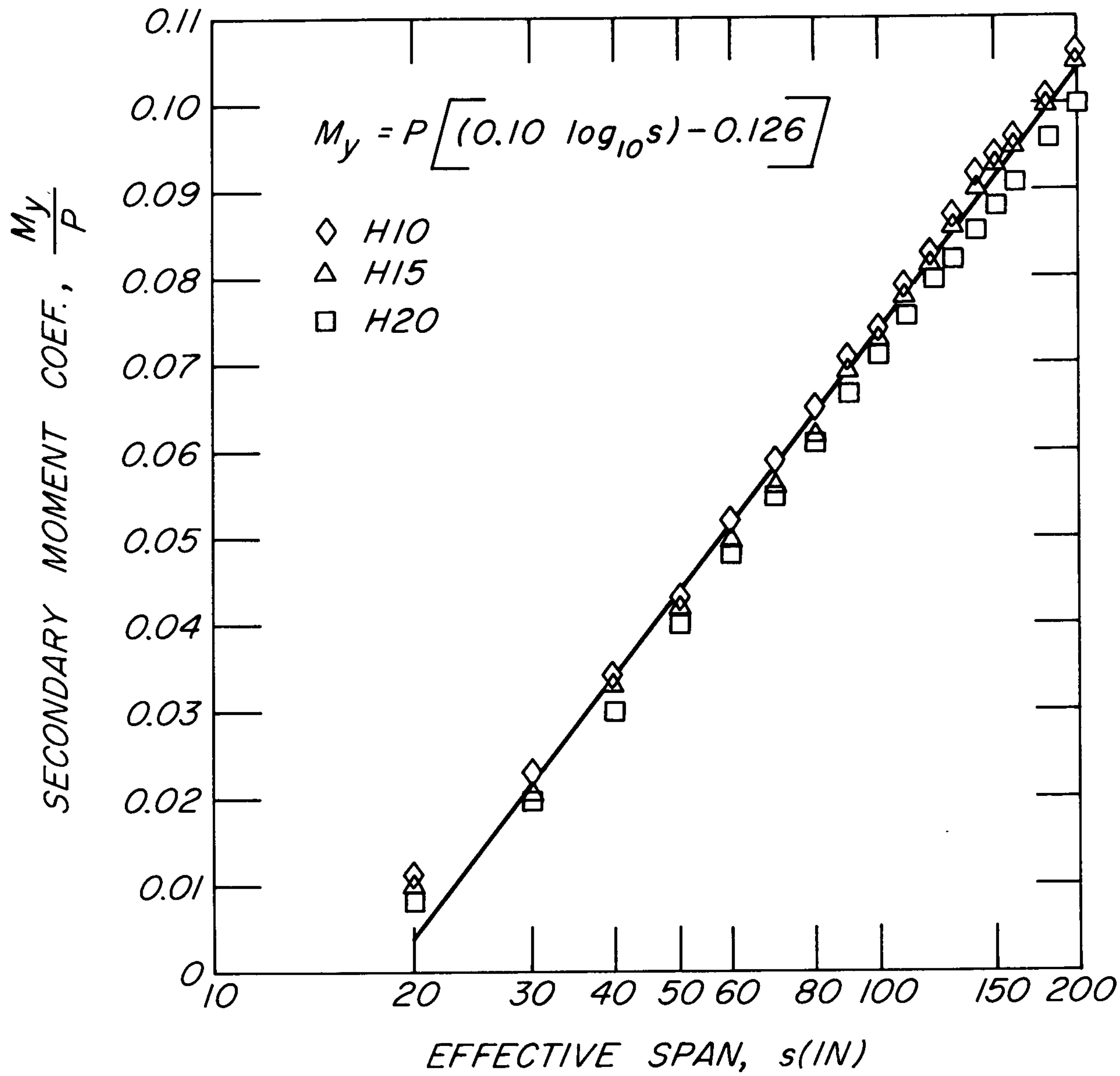


Figure 3.—Secondary moment coefficients M 142 114

Figure 5 shows the curve plotted for the deck deflection, w (inch). The corresponding eauation is

$$w = 0.51\frac{Ps}{E_x t^3}(s - 10)$$

where E_x = modulus of elasticity parallel to grain (pound per square inch) and

t = deck thickness (inch)

The above equations are summarized in table 1. Primary and secondary bending stresses can be calculated from the unit bending moments (M_x and M_y) and are equal to $6M/t^2$. Shear stresses are equal to 3R/2t.

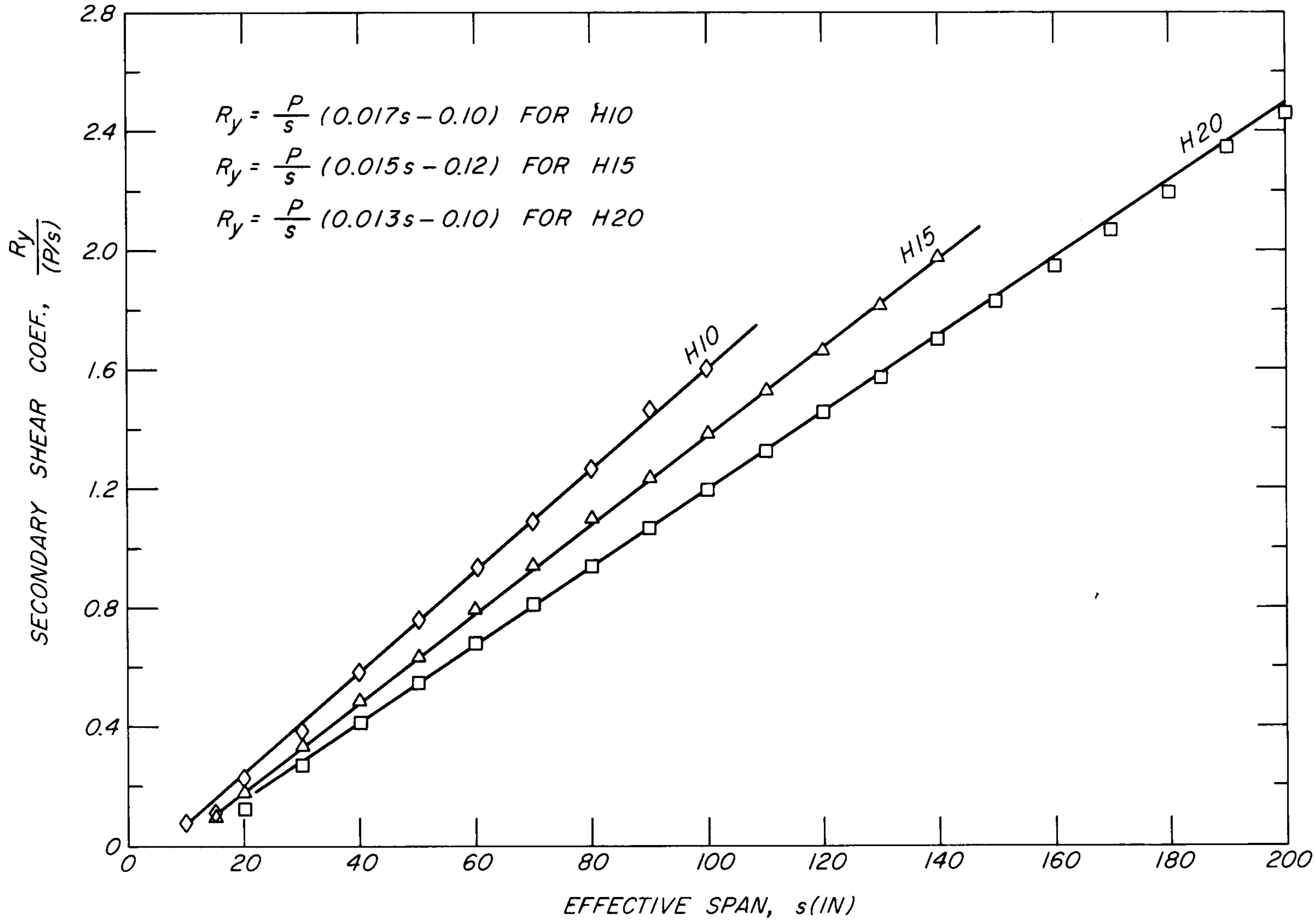
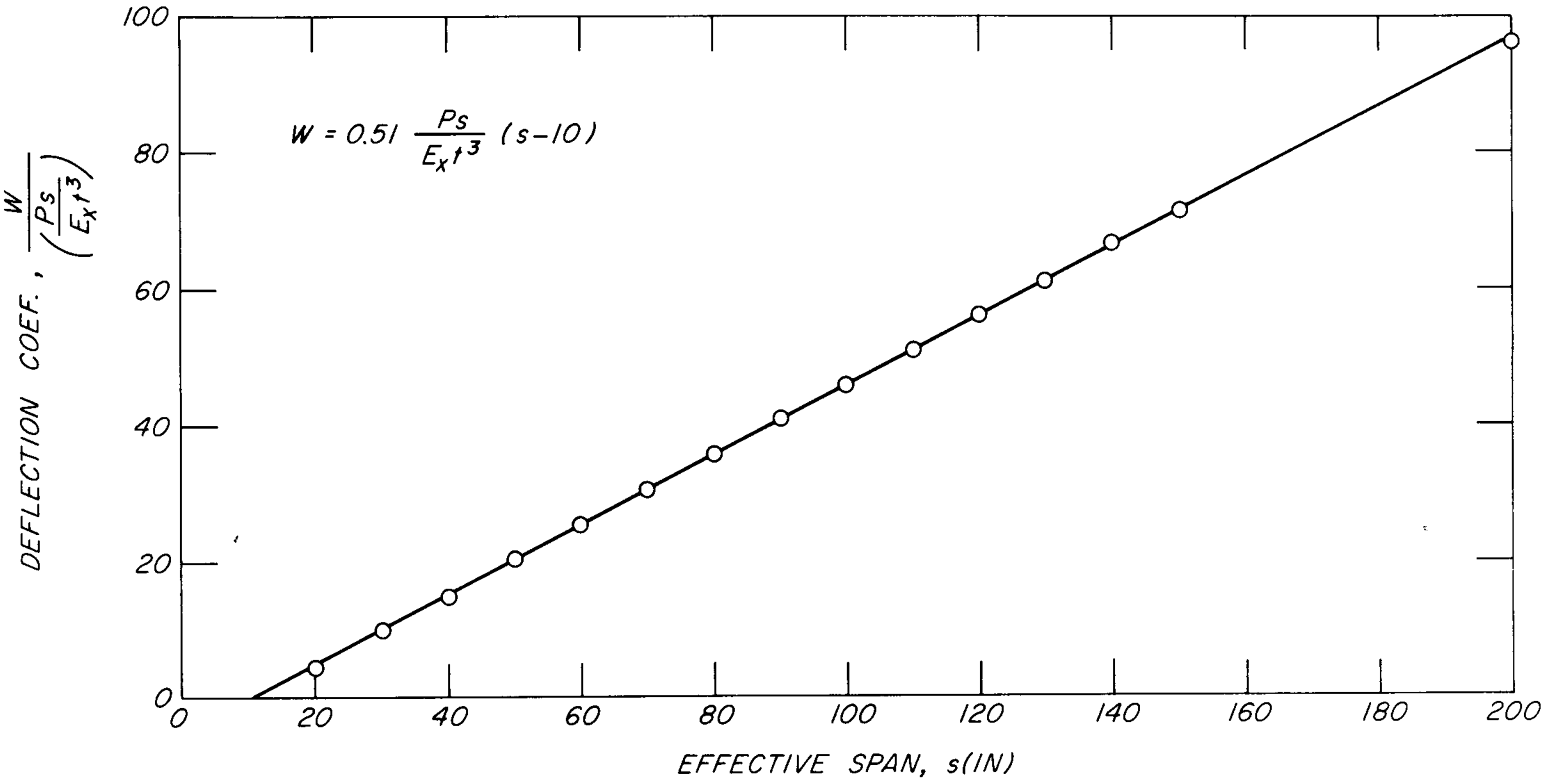


Figure 4.—Secondary shear coefficients

M 142 115



M 142 116

Figure 5.—Deflection coefficients

Table 1.—Deck design equations [3]

Unit moments, shears, and deflection	Computation equations for AASHO truck loads		
	H10	H15	H20
Primary moment, M_x (in.-lb/in.)	$P[(0.51 \log s) - 0.44]$	$P[(0.51 \log s) - 0.47]$	$P[(0.51 \log s) - 0.51]$
Primary shear, R_x (lb/in.)	$0.034P$		
Secondary moment, M_y (in.-lb/in.)	$P[(0.10 \log s) - 0.126)]$		
Secondary shear, R_y (lb/in.)	$\frac{P}{s}(0.017\ s - 0.10)$	$\frac{P}{s}(0.015\ s - 0.12)$	$\frac{P}{s}(0.013\ s - 0.10)$
Deflection, w (in.)	$0.51 \frac{Ps}{E_x t^3}(s - 10)$		

P = wheel load (pound)
s = effective deck span (inch)
E_x = longitudinal modulus of elasticity (pound per square inch)
t = deck thickness (inch)

EQUATIONS FOR DOWEL DESIGN

The total secondary moment and shear are needed to compute the size and number of steel dowel connectors. Figure 6 shows the curve which was plotted for the total moment, M_y (inch-pound). The equations which define this curve are

$$\overline{M}_y = \frac{Ps}{1,600}(s - 10) \text{ for } s \leq 50 \text{ in.}$$

$$= \frac{Ps}{20}\left(\frac{s - 30}{s - 10}\right) \text{ for } s > 50 \text{ in.}$$

Similarly, the equations derived for the total secondary shear, R_y (pound), as determined from figure 7, are

$$\overline{R}_y = \frac{6Ps}{1,000} \text{ for } s \leq 50 \text{ in.}$$

$$= \frac{P}{2s}(s - 20) \text{ for } s > 50 \text{ in.}$$

These two relationships are shown in table 2.

The number of dowel connectors required can be computed from the information in table 3 (which is repeated in a slightly abbreviated form from FPL 210) and the equation

$$n = \frac{1,000}{\sigma PL}\left[\frac{\overline{R}_y}{R_D} + \frac{\overline{M}_y}{M_D}\right]$$

R_D, M_D = dowel shear and moment capacities, table 3

σ PL = proportional limit stress of deck material in compression perpendicular to grain, pound per square inch

The proportional limit stress, σ PL, is approximately 1,000 lb/in.^{2} for southern pine and Douglas-fir. For other species consult the Wood Handbook,[4] table 12.

Although it is unlikely that steel stresses will control the joint design, except for the smallest dowel sizes, they must nevertheless be checked by

$$f = \frac{1}{n}(C_R \overline{R}_y + C_M \overline{M}_y)$$

where $C_R C_M$ = stress coefficients, table 3.

The stress thus computed, f (pound per square inch), must not exceed the AASHO allowable stress in extreme fibers of pins.

[4] *Forest Products Laboratory. Wood Handbook. USDA Agriculture Handbook 72. 1955.*

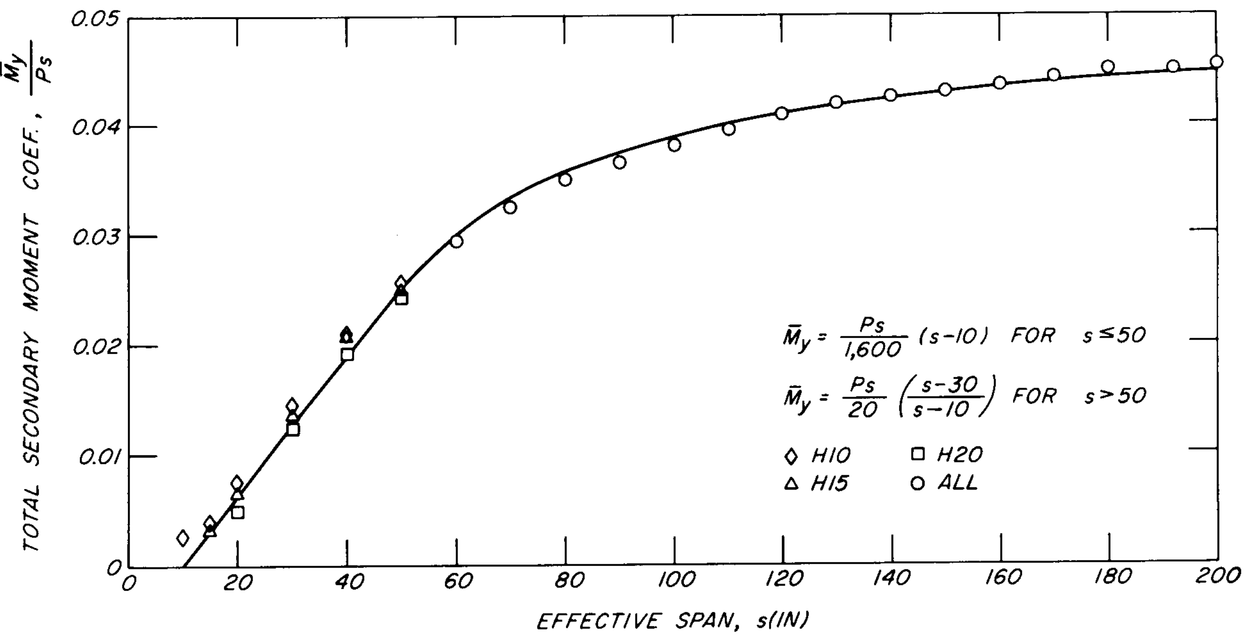


Figure 6.—Total secondary moment co-efficients

M 142 117

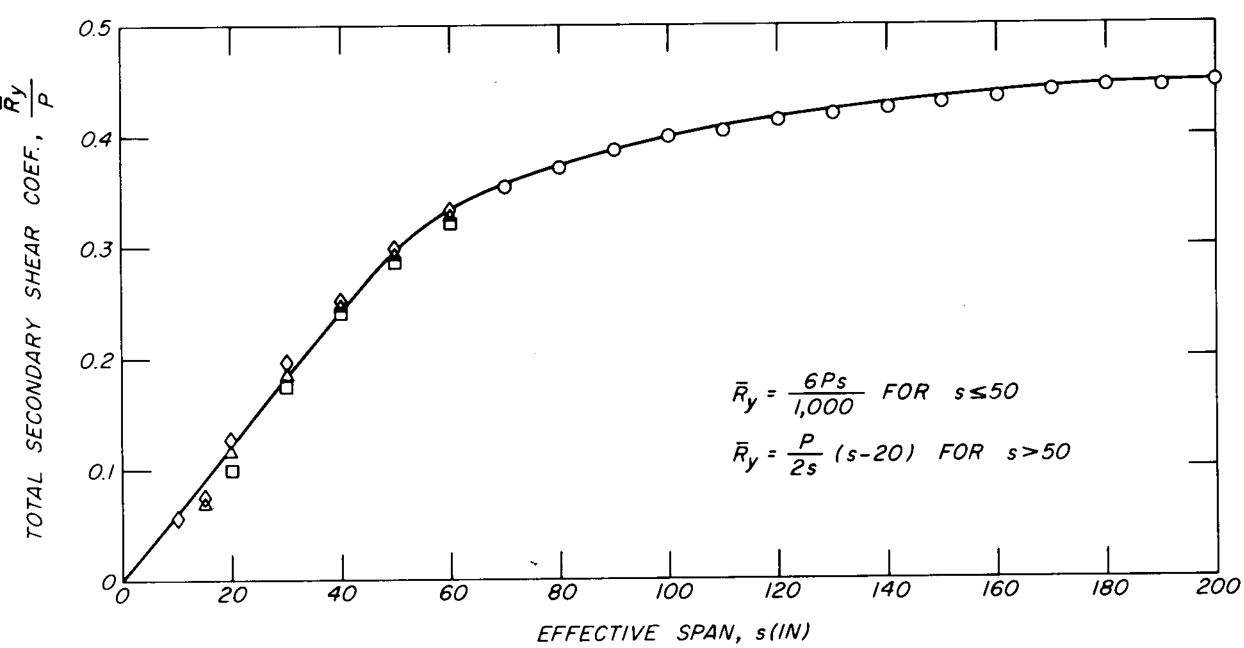


Figure 7.— Total secondary shear coefficients

M 142 118

Table 2.—Total secondary moment and shear for dowel design

Total secondary moment or shear	Effective span	
	$s \leq 50$	$s > 50$
Total secondary moment, $\bar{M}_y$ (in.-lb)	$\frac{Ps}{1,600}(s-10)$	$\frac{Ps}{20}\left[\frac{s-30}{s-10}\right]$
Total secondary shear, $\bar{R}_y$ (lb)	$\frac{6Ps}{1,000}$	$\frac{P}{2s}(s-20)$

P = wheel load (pound).
s = effective deck span (inch).

Table 3.—Dowel design data

Diameter, d	Shear capacity, R_D	Moment capacity, M_D	Steel stress coefficients		Total dowel length
			C_R	C_M	
In.	Lb	In.-1b	1/in.^{2}	1/in.^{3}	In.
0.5	600	850	36.9	81.5	8.5
.625	800	1,340	22.3	41.7	10.0
.75	1,020	1,960	14.8	24.1	11.5
.875	1,260	2,720	10.5	15.2	13.0
1.0	1,520	3,630	7.75	10.2	14.5
1.125	1,790	4,680	5.94	7.15	15.5
1.25	2,100	5,950	4.69	5.22	17.0
1.375	2,420	7,360	3.78	3.92	18.0
1.5	2,770	8,990	3.11	3.02	19.5

CONCLUSION

When designing glued-laminated bridge decks for the standard AASHO H10, H15, or H20 trucks, the above equations can be used in place of the original design curves. These equations are summarized for ease of reference in tables 1 to 3. Once the moments and shears have been computed, the rest of the design procedure is exactly as originally presented.