

Editors

**ENGINEERING
TECHNICAL
INFORMATION
SYSTEM**

FIELD NOTES • TECHNICAL REPORTS
DATA RETRIEVAL • MANAGEMENT
PROFESSIONAL DEVELOPMENT

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Field



Notes

Design Alternatives for Low-Volume
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Design Guide for Native Log Stringer Bridges

Analysis and Load Rating of Native Log Stringer
Bridges

Washington Office News



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FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
Washington, D.C. 20250

DESIGN ALTERNATIVES FOR LOW - VOLUME FOREST ROADS

Russ Huskey
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Region 4

INTRODUCTION

Low standard, local roads are the largest workload for engineers involved in road construction on the Boise National Forest. The present methods for survey, design, and construction of designated-system roads vary little—only in precision—from one “standard” to another.

Surveys vary from staff compass and cloth tape horizontal control to automated distance-measuring devices. Vertical control varies from hand level to automatic level.

Designs are completed in the field, or are computed manually, or are run through the Fort Collins Computer Center (FCCC) with limited variations in methods and mostly for only the high-precision surveys. Recognizing that design computations can be automated for the low-precision surveys, we organized and presented a system to process computations for the low-precision applications on low-volume roads. The following methods are alternatives to present practices and can bring economics and environmental protection into focus.

METHOD I

This method involves running a percent abney level (PAL) survey for vertical control and horizontal distance. Horizontal alignment is set in the field by field “flag line” and is not surveyed. The engineer who has established the flag line transfers the location to aerial photography or maps. Final field vertical centerline control is established by using two range poles, two abneys, and a cloth tape. Survey stakes should be placed at some minimal interval and at vertical breaks. The slope distances between stations are measured between the range pole’s H.I. points. Next, cross sections are taken. The staked centerline is laid out to provide horizontal curvature that will facilitate traffic. Thus, the original line is the L-line.

These survey notes are recorded in a format acceptable to the computer. Exhibits of PAL survey notes for computer reduction, with horizontal bearings run on the P-line, are shown in the RDS

handbook. A figure for a “bearing” to complete the reduction of raw field notes must be inserted in the computer.

As indicated in the RDS handbook, all stations in the field are marked with a section number to identify the station on the ground. The section numbers that end with two zeros, such as 100, 2,400, or 10,400, are horizontal angle points. Those ending in two digits other than “00” are intermediate points such as 2,401, 102, 5,010. After reduction, true horizontal distances are computed and are assigned to these field points, P-ground elevations are computed also.

The first station point on the ground is indicated as “00” to introduce a horizontal turning point. All the points thereafter, except the last point, are recorded with the last two digits not zeros to indicate intermediate points.

These intermediate section numbers are recorded in a manner that shows an increase in the number running down the P-line. They are stored in the computer in this order to prevent overlaps. The last section number is recorded with two zeros; these last two digits indicate to the computer that all stations between “00” and the last or end section are intermediate points. This will enable the designer to record one bearing at the first section to provide horizontal control information and meet the requirements of the program.

RDS design programs are very versatile; variations on input and utilization of the program enables design earthwork to be computed without using the complete system. To compute design earthwork, the following card types must be generated by the HAL-OFFSETS-Roadway phase, or substituted by manual methods—the c.t. 49 offsets and the c.t. 40 template data. Offsets (c.t. 49’s) are used only on stations that are offset from the P-line. Thus, for Method I, c.t. 49’s are not needed.

The roadway program may be run to generate templates; or c.t. 40’s (manual templates) may be used. To obtain output of design earthwork, clearing and seeding acres, and stakeout notes, input only the following record types: 20’s (profile grade data), 30’s (slope section data), 35’s (compaction factor), 40’s (template data), and 50’s (topography data).

The plan and profile can be drafted in many formats. If there is a need to show the horizontal location, a map or aerial photo can be included with the profile views (Figure 1).

Construction stakes are set by using the computer-generated slope-stake notes as field tables. Stakes are set on the uphill side and flags on the downhill side at the horizontal and vertical distances on the printout. At least one in five sections and all culvert locations are set by conventional methods with a reference stake. Variations in staking should be determined by needs of resource and accuracy.

METHOD II

This method is similar to Method I; however, it provides the designer with an element of horizontal control. The survey also uses the PAL method, with a staff compass to provide horizontal control. The format for survey notes is shown in the RDS handbook.

The design input to RDS for this method differs from Method I only in one respect—the input of c.t. 49's, manual offsets, at desired locations. The P-line is plotted as other projects are, with horizontal control. Designs of horizontal curves are replaced with chords to simulate curvature. The designer must be careful not to offset from the P-line if it is not necessary. Offsets are used only to improve alignment and fit the topography. RDS will offset only those sections for

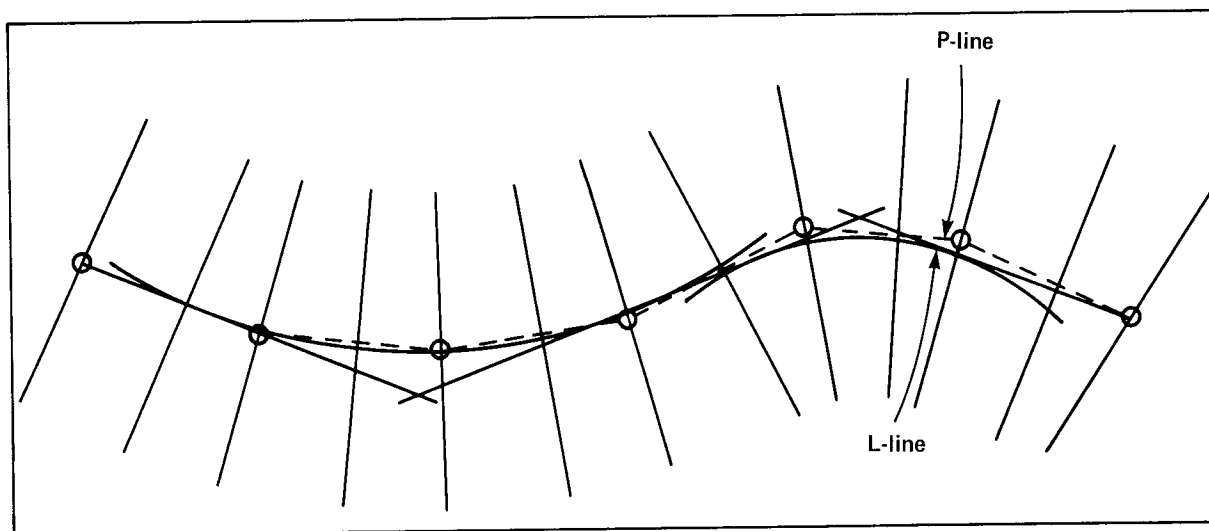


Figure 2. Automatic offsets with curves.

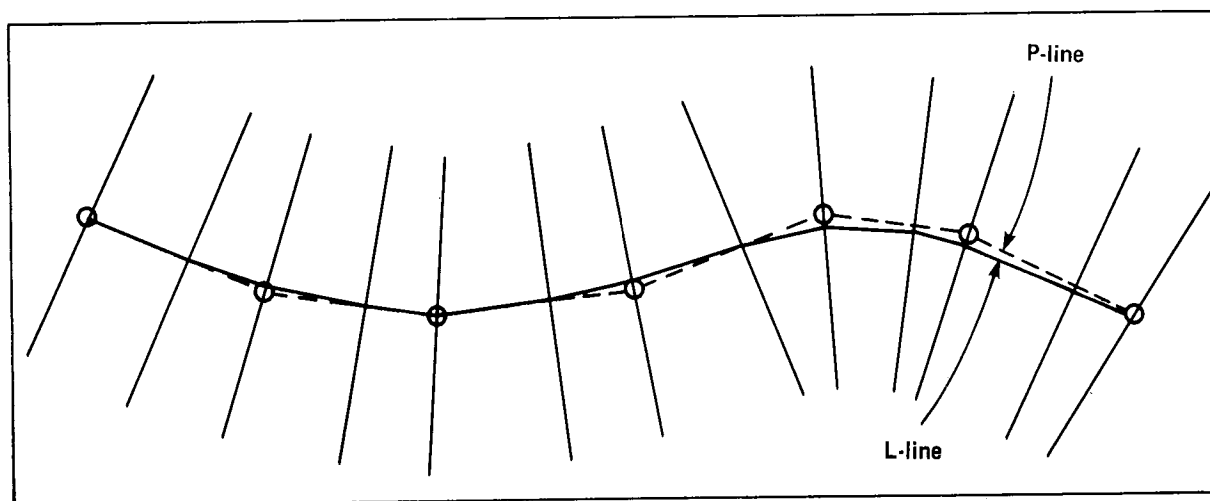


Figure 3. Manual offsets with chords. (P-line and L-line stationing are the same.)

which a c.t. 49 has been entered. The main elements involved are good field location and proper alignment of the P-line. When surveys are made with inexperienced personnel, more offsets will be required. The methods of manual offsets and chorded alignment are shown in Figures 2 and 3.

The error of distance that occurs in the L-line when the P-line station becomes the L-line station with a manual offset is minimal. It is obvious that the greater the offset is, the greater the error is in actual horizontal distance. The error in true horizontal distance will reflect some change in the percent of grade. The error in percent of grade of Rock Creek Road, No. 10238 (Figure 1), designed and constructed during FY 1973, had a maximum of 0.3 percent. For low standard road construction, this is insignificant.

The plan and profile for Method II are similar to any other; however, the plan view shows chorded alignment rather than radius curves. The plans drawn show the design alignment as offset from the P-line. The stationing is P-line station, as the "P" and "L" stations remain the same. "L" profile elevation and grades are computed by the RDS program.

Construction stakes are set with a cloth tape, a hand level, and a level rod. All points on the uphill side, culvert locations on both sides, and selected stations are slope staked. Reference stakes (R. P.'s) are set every 100 feet, and flagging is tied on the downhill catchpoints to define the construction limits. The catchpoints on the downhill side are located by chaining the distance indicated in the computer-generated slope stake notes.

SUMMARY

The two methods are intended to reduce the required number of man-hours to complete a product and to maintain control to protect the resource. These two methods, used in any combination with existing practices, broaden the base for engineering applications. Savings can range from 27 to 71 percent, depending on the method. The two methods are summarized in the cost comparison, Table 1. The average savings per mile will be:

$$(2,910) - \frac{(540+980)}{2} = \$2,150.$$

Table 1. Cost comparisons

METHOD	SURVEY	DESIGN & PLANS	CONSTRUCTION STAKING	TOTAL COST
I	(PAL) without horizontal control \$180/mile	Design earthwork without horizontal control \$180/mile	Computer stakeout notes used as tables \$180/mile	 \$540/mile
II	(PAL) with staff compass for horizontal control \$240/mile	Design earthwork with manual offsets for horizontal control \$330/mile	Slope stakes up-hill side and culvert locations \$410/mile	 \$980/mile
Regular Methods	Regular survey with staff compass for horizontal control \$620/mile	Regular RDS design and plans plotted by computer \$440/mile	Regular construction survey based on offsets from P-line \$1,850/mile	 \$2,910/mile

DESIGN GUIDE FOR NATIVE LOG STRINGER BRIDGES

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Region 10

The design guide for native log stringer bridges is intended to present basic design criteria to enable the engineer in the field to readily and accurately determine whether single lane native log stringer bridges are designed and constructed to safely support specific loadings and meet minimum safety criteria.

The guide can also be used to determine the live-load capacity rating of existing log stringer bridges when span length, stringer species, size and condition, and depth of rock fill are known.

The AASHTO Type 3, 3S2, and 3-3 vehicles are used to rate the bridges, and the procedure for rating existing bridges should conform to that given in the *Manual for Maintenance Inspection of Bridges 1974*, AASHTO.

Each bridge may be rated at two stress levels:

OPERATING RATING. The first, or upper, stress level at working unit stresses not to exceed 1.33 of the normal allowable stresses. The operating rating stress is the absolute maximum permissible stress level to which a structure may be safely subjected.

INVENTORY RATING. The second, or lower, stress level at working unit stresses equal to the normal allowable stresses.

Typical Bridge

This procedure applies to log stringer superstructures consisting of longitudinal log stringers placed butt-to-tip and lashed together. Poles should be used to chink between logs. The stringers are lashed together with cables at each abutment, with additional lashing to be used for longer spans (see design criteria). Broken blast rock or crushed rock is placed directly on the stringers and serves as the running surface. Brow logs should be used for safety curbs. Abutments may consist of mud-sill only, mud-sill and wing logs, log-crib, post and sill, or piling (see Figure 1, typical detail sheet).

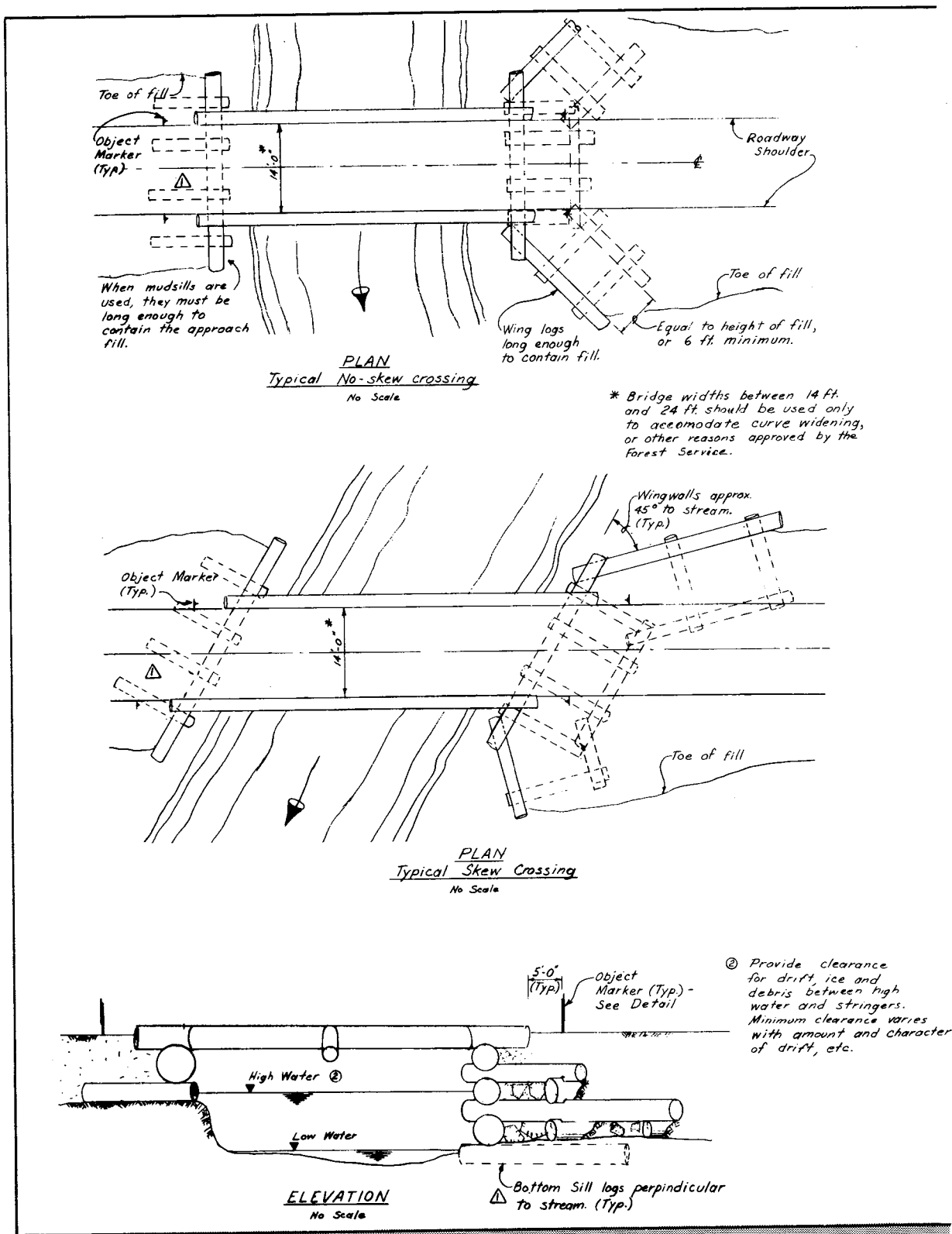
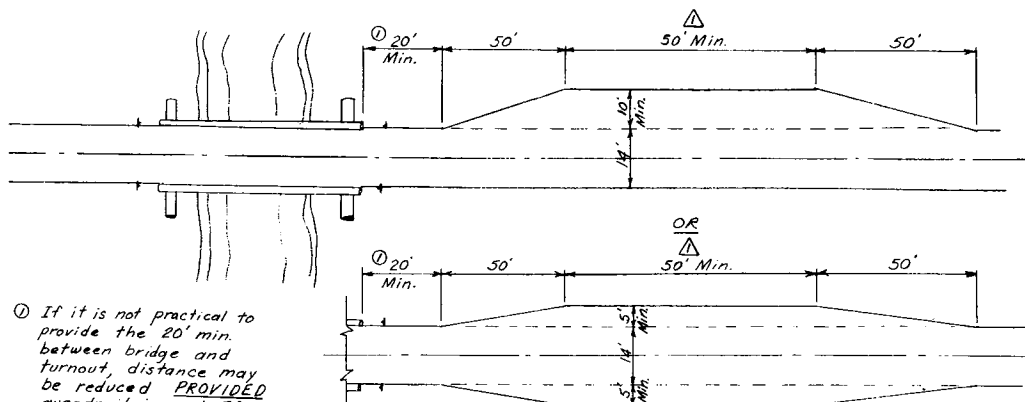
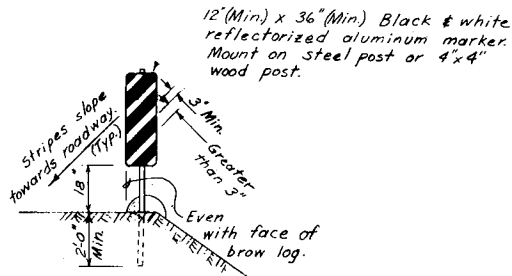
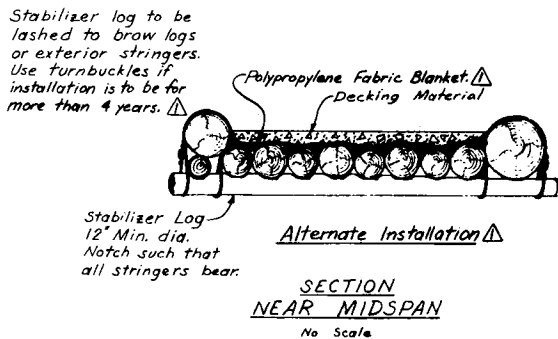
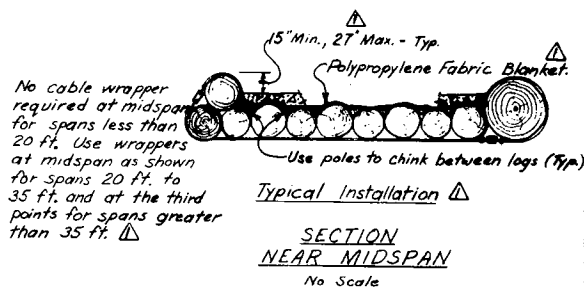
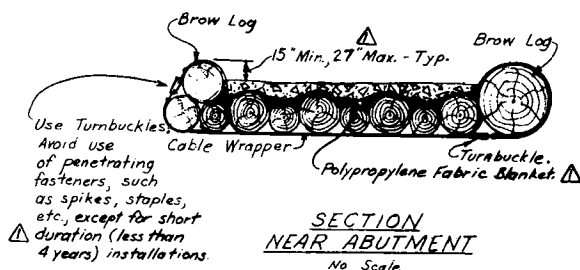


Figure 1. Typical detail sheet for log stringer bridges. (U.S. Department of Agriculture—Forest Service: The Alaska Region)



TURNOUT DETAIL
No Scale



NOTE:

Decking material to be 12" max. thickness (average) of select blast-rock or crushed rock. No rock larger than 1/2 the surfacing thickness shall be used.

It may require more stringers than the design calculations call for to construct the bridge. If brow logs are used as shown on the left side of the typical sections above, an additional stringer on each side will be required.

SHEET 1 OF 1

Revised - 9/3/75

DESIGNED <i>FWM</i>	DRAWN <i>FWM</i>
SUBMITTED <i>Frank W. Mackmore</i>	DATE <i>9/5/76</i>
APPROVED <i>URK</i>	DATE <i>9/6/74</i>

DESIGN CRITERIA

The design procedure is based on the following criteria:

DEAD-LOAD DISTRIBUTION. It is assumed that each stringer carries its own dead-load and that portion of the rock fill which is directly over the stringer. Forty pcf was used as the unit weight of wood and 120 pcf as the unit weight of rock fill.

LIVE-LOAD DISTRIBUTION. It is assumed that the live-load is distributed to the stringers as follows:

Bending. The live-load bending moment distribution factor (that portion of the total bending moment applied to one stringer) shall be:

For rock fills 2 feet or less in depth, 30 percent of the truck bending moment shall be applied to any one stringer.

Distribution factor = 0.3.

For rock fills over 2 feet in depth, the truck bending moment shall be equally distributed to all stringers wholly within a width of $W = (6 + 1\frac{3}{4}d)$ feet, where d = depth of rock fill.

Distribution factor = $1/(\text{No. of stringers determined above})$ but not to exceed 0.3.

For L70 or L90 Log Loaders, the bending moment may be considered to be equally distributed to all stringers in the bridge (but not brow logs).

Distribution factor = $1/(\text{No. of stringers})$.

Shear. Stringers properly designed for bending moment will resist shear effectively with the possible exception of short spans (under 20 feet). For spans under 20 feet, stringers with a section modulus (Table 1) approximately 25 percent greater than required for bending should be used to increase the shear resistance.

Allowable Bending Stress

Allowable bending stresses are based on the methods and data outlined in ASTM D2899, D25

Use of these stresses is dependent on high quality, straight, sound logs, free of wind shake, decay, excessive twist (spiral grain more than 1 in 8), and all defects that may considerably affect their strength. Knot size in the middle half of the length should not exceed 5 inches, and stringers with large knots opposite each other should not be used.

Stringer Diameters

Stringer diameters given are average midspan diameters *inside* of bark. Such diameter is considered as the average of the diameters of all stringers in the bridge.

Table 1. Properties of circular sections

DIAM (IN)	CIRCUM (IN)	AREA (SQ.IN.)	DL LOG (LB/FT)	DL DECK (LB/FT)	SEC MOD (IN**3)	MOM INERT (IN**4)
10	31.4	78.5	21.8	100.0	98.1	490.8
11	34.5	95.0	26.3	110.0	130.6	718.6
12	37.6	113.0	31.4	120.0	169.6	1017.8
13	40.8	132.7	36.8	130.0	215.6	1401.9
14	43.9	153.9	42.7	140.0	269.3	1885.7
15	47.1	176.7	49.0	150.0	331.3	2485.0
16	50.2	201.0	55.8	160.0	402.1	3216.9
17	53.4	226.9	63.0	170.0	482.3	4099.8
18	56.5	254.4	70.6	180.0	572.5	5152.9
19	59.6	283.5	78.7	190.0	673.3	6397.1
20	62.8	314.1	87.2	200.0	785.3	7853.9
21	65.9	346.3	96.2	210.0	909.1	9546.5
22	69.1	380.1	105.5	220.0	1045.3	11499.0
23	72.2	415.4	115.4	230.0	1194.4	13736.6
24	75.3	452.3	125.6	240.0	1357.1	16286.0
25	78.5	490.8	136.3	250.0	1533.9	19174.7
26	81.6	530.9	147.4	260.0	1725.5	22431.7
27	84.8	572.5	159.0	270.0	1932.3	26087.0
28	87.9	615.7	171.0	280.0	2155.1	30171.8
29	91.1	660.5	183.4	290.0	2394.3	34718.5
30	94.2	706.8	196.3	300.0	2650.7	39760.7
31	97.3	754.7	209.6	310.0	2924.7	45333.1
32	100.5	804.2	223.4	320.0	3216.9	51471.8
33	103.6	855.2	237.5	330.0	3528.1	58213.7
34	106.8	907.9	252.1	340.0	3858.6	65597.1
35	109.9	962.1	267.2	350.0	4209.2	73661.6
36	113.0	1017.8	282.7	360.0	4580.4	82447.8
37	116.2	1075.2	298.6	370.0	4972.8	91997.5
38	119.3	1134.1	315.0	380.0	5387.0	102353.7
39	122.5	1194.5	331.8	390.0	5823.6	113560.6
40	125.6	1256.6	349.0	400.0	6283.1	125663.6
41	128.8	1320.2	366.7	410.0	6766.2	138709.1
42	131.9	1385.4	384.8	420.0	7273.5	152744.8
43	135.0	1452.1	403.3	430.0	7805.5	167819.8
44	138.2	1520.5	422.3	440.0	8362.9	183984.0
45	141.3	1590.4	441.7	450.0	8946.1	201288.7
46	144.5	1661.9	461.6	460.0	9555.9	219786.4
47	147.6	1734.9	481.9	470.0	10192.7	239530.5
48	150.7	1809.5	502.6	480.0	10857.3	260576.0
49	153.9	1885.7	523.8	490.0	11550.1	282978.7
50	157.0	1963.4	545.4	500.0	12271.8	306795.8
51	160.2	2042.8	567.4	510.0	13022.9	332085.7
52	163.3	2123.7	589.9	520.0	13804.1	358907.8
53	166.5	2206.1	612.8	530.0	14615.9	387322.7
54	169.6	2290.2	636.1	540.0	15458.9	417392.4
55	172.7	2375.8	659.9	550.0	16333.8	449179.8
56	175.9	2463.0	684.1	560.0	17241.0	482749.2
57	179.0	2551.7	708.8	570.0	18181.2	518166.0
58	182.2	2642.0	733.9	580.0	19155.0	555496.7
59	185.3	2733.9	759.4	590.0	20163.0	594809.0
60	188.4	2827.4	785.3	600.0	21205.7	636171.9

Bridge Width

Minimum width between brow logs shall be 14 feet. Bridge widths between 14 and 24 feet should be used only to accommodate a curve widening (see FSM 7718.22) or for other justifiable reasons.

Rock Depth

The average depth of rock fill should be kept to a minimum, especially on the longer span bridges. The following formula should be used unless there is good reason to increase the average rock depth.

- Spans less than 20 feet – 12 inches.
- Spans less than 35 feet – 6 to 12 inches.
- Spans more than 35 feet – 6 inches.

Lashing

Stringers should be lashed together with a 3/4-inch minimum diameter wire rope. Turnbuckles should be used, and driving penetrating fasteners (nails, spikes, staples, etc.) should be avoided if possible. Minimum lashing shall be as follows:

- Spans less than 20 feet – at abutments only.
- Spans 20 feet to 35 feet – at abutments and midspan.
- Spans greater than 35 feet – at abutments and stabilizer log at midspan.

PROCEDURE

The log stringer section properties, allowable bending stresses, dead-load moments, and resisting moments have been tabulated in Tables 1 through 5. Table 6 gives live-load bending moments for various vehicles. Approximate stringer diameters required are given in Table 7.

Design

The basic design approach is as follows:

- Step 1.* Determine allowable stress from Table 2.
- Step 2.* Find approximate stringer diameter required from Table 7.
- Step 3.* Enter Table 3 with span length and approximate stringer diameter. Determine dead-load bending moment due to dead-load of stringer.
- Step 4.* Enter Table 4 with span length and approximate stringer diameter. Determine dead-load bending moment due to dead-load of rock fill. If 12

inches of fill are not used, take the ratio of actual depth to be used, to 12 inches.

- Step 5.* Enter Table 6 with span length, and determine live-load bending moment.
- Step 6.* Multiply the live-load bending moment (Step 5) by the live-load distribution factor. (See live-load, under design criteria.)
- Step 7.* Add dead-load bending moments due to stringer and rock deck to distributed live-load bending moment, to determine total bending moment.
- Step 8.* Enter Table 5 with stringer diameter and allowable bending stress. Determine allowable bending moment.
- Step 9.* Compare total bending moment (Step 7) to allowable bending moment (Step 8). Adjust stringer size if necessary, and repeat Steps 3 through 8.

Example 1.

Given: Span length 45 feet

U80 loading for lifetime of bridge, with occasional L90 loading.
Sitka spruce stringers with 6 inches of rock fill.

- Step 1.* Allowable bending stress from Table 2 = 1,600 psi.
- Step 2.* Approximate stringer diameter required (Table 7) = 32 inches.
- Step 3.* Dead-load bending moment for 32-inch diameter stringer = 56.5 ft. kips (Table 3).
- Step 4.* Dead-load bending moment for 6-inch rock deck = $81.0 \text{ (Table 4)} \times 6/12 = 40.5 \text{ ft. kips.}$
- Step 5.* Live-load bending moment (Table 6) = 1,028 ft. kips.
- Step 6.* Distributed live-load bending moment = $1,028 \times 0.3 = 308.4 \text{ ft. kips.}$
- Step 7.* Total moment = $56.5 + 40.5 + 308.4 = 405.4 \text{ ft. kips.}$
- Step 8.* Allowable bending moment (Table 5) = 428 ft. kips.
Therefore, 32-inch stringers are O.K. Use 6 stringers.

Check for L90 Loading

- Step 1.* Allowable bending stress = 2,100 psi (Table 2, for one-time loading).

- Step 2.* 32-inch stringer from above.
- Steps 3 & 4* Dead-load moments same as above.
- Step 5.* Live-load bending moment (Table 6) = 1,688 ft. kips.
- Step 6.* Distributed live-load bending moment = $1,688 \times 1/6 = 281$ ft. kips.
- Step 7.* Total moment = $56.5 + 40.5 + 281 = 378$ ft. kips.
- Step 8.* Allowable bending moment (Table 5) = 562 ft. kips.
Therefore, 32-inch stringers are O.K.

Analysis of Existing Structures

Analysis for loading capacity should be done as follows:

- Step 1.* Determine allowable bending stress (Table 2 and inspection report) for inventory and operating ratings.
- Step 2.* Enter Table 3 with span length and average stringer diameter. Determine dead-load bending moment due to stringer.
- Step 3.* Enter Table 4 with span length and average stringer diameter. Determine dead-load bending moment due to 12 inches of rock fill and ratio to actual depth of fill.
- Step 4.* Enter Table 5 with average stringer diameter. Determine allowable bending moment.
- Step 5.* Subtract dead-load bending moment due to stringer and rock fill from allowable bending moment to determine available live-load bending moment per stringer.
- Step 6.* Divide available live-load bending moment by the distribution factor to determine the total available live-load bending moment.
- Step 7.* Divide total available live-load bending moment by the tabulated live-load bending moment (Table 6), and multiply by the gross weight of the rating vehicle in tons, to determine the live-load capacity of the structure in tons for that configuration of vehicle.

Example 2.

Determine the operating and inventory rating for the following bridge.

Given: Bridge length 55 feet

Average stringer diameter = 31 inches.
Average depth rock deck = 15 inches.
Spruce stringers.

- Step 1.* Allowable stress (Table 2).
 (a) Operating stress = 2,100 psi.
 (b) Inventory stress = 1,600 psi.
- Step 2.* Dead-load bending moment due to stringer (Table 3) = 79.2 ft. kips.
- Step 3.* Dead-load bending moment due to rock fill (Table 4) = $117.2 \times 15/12 = 146.5$ ft. kips.
- Step 4.* (a) Operating allowable moment (Table 5, for 2,100 psi) = 511 ft. kips.
 (b) Inventory allowable moment (Table 5, for 1,600 psi) = 389 ft. kips.
- Step 5.* (a) Available operating live-load moment per stringer = $511 - (79.2 + 146.5) = 285.3$ ft. kips.
 (b) Available inventory live-load moment per stringer = $389 - (79.2 + 146.5) = 163.3$ ft. kips.
- Step 6.* (a) Total available operating live-load bending moment = $285.3 \div 0.3 = 951$ ft. kips.
 (b) Total available inventory live-load bending moment = $163.3 \div 0.3 = 544.3$ ft. kips.
- Step 7.* (a) Operating rating for:
 1. Type 3 vehicle = $(951/497) \times 23 = 44$ tons.
 2. Type 3S2 vehicle = $(951/536) \times 36 = 64$ tons.
 3. Type 3-3 vehicle = $(951/449) \times 37 = 78$ tons.
- (b) Inventory rating for:
 1. Type 3 vehicle = $(544.3/497) \times 23 = 25$ tons.
 2. Type 3S2 vehicle = $(544.3/536) \times 36 = 37$ tons.
 3. Type 3-3 vehicle = $(544.3/449) \times 37 = 45$ tons.

Table 2. Allowable bending stress

USE	ALLOWABLE STRESS (PSI)			
	SITKA SPRUCE ¹	HEMLOCK ¹	DOUGLAS FIR ²	W. LARCH ²
Lifetime of bridge ³ (8-10 years) Inventory rating	1,600	1,800	2,000	2,000
1-2 years	1,800	2,000	2,300	2,300
One-time overload ³ (on permit basis) Operating rating	2,100	2,400	2,600	2,600

¹Based on clearwood strength values established by FPL, and set forth in FPL-1.

²Based on clearwood strength values set forth in ASTM D2555-73.

³Derived in accordance with ASTM D2899-70T - 7/29/74 - R10.

Table 3. Dead-load bending moments

DIA	SPAN									
	10	15	20	25	30	35	40	45	50	55
10	0.2	0.6	1.0	1.7	2.4	3.3	4.3	5.5	6.8	8.2
11	0.3	0.7	1.3	2.0	2.9	4.0	5.2	6.6	8.2	9.9
12	0.3	0.8	1.5	2.4	3.5	4.8	6.2	7.9	9.8	11.8
13	0.4	1.0	1.8	2.8	4.1	5.6	7.3	9.3	11.5	13.9
14	0.5	1.2	2.1	3.3	4.8	6.5	8.5	10.8	13.3	16.1
15	0.6	1.3	2.4	3.8	5.5	7.5	9.8	12.4	15.3	18.5
16	0.6	1.5	2.7	4.3	6.2	8.5	11.1	14.1	17.4	21.1
17	0.7	1.7	3.1	4.9	7.0	9.6	12.6	15.9	19.7	23.8
18	0.8	1.9	3.5	5.5	7.9	10.8	14.1	17.8	22.0	26.7
19	0.9	2.2	3.9	6.1	8.8	12.0	15.7	19.9	24.6	29.7
20	1.0	2.4	4.3	6.8	9.8	13.3	17.4	22.0	27.2	32.9
21	1.2	2.7	4.8	7.5	10.8	14.7	19.2	24.3	30.0	36.3
22	1.3	2.9	5.2	8.2	11.8	16.1	21.1	26.7	32.9	39.9
23	1.4	3.2	5.7	9.0	12.9	17.6	23.0	29.2	36.0	43.6
24	1.5	3.5	6.2	9.8	14.1	19.2	25.1	31.8	39.2	47.5
25	1.7	3.8	6.8	10.6	15.3	20.8	27.2	34.5	42.6	51.5
26	1.8	4.1	7.3	11.5	16.5	22.5	29.4	37.3	46.0	55.7
27	1.9	4.4	7.9	12.4	17.8	24.3	31.8	40.2	49.7	60.1
28	2.1	4.8	8.5	13.3	19.2	26.1	34.2	43.2	53.4	64.6
29	2.2	5.1	9.1	14.3	20.6	28.0	36.6	46.4	57.3	69.3
30	2.4	5.5	9.8	15.3	22.0	30.0	39.2	49.7	61.3	74.2
31	2.6	5.8	10.4	16.3	23.5	32.1	41.9	53.0	65.5	79.2
32	2.7	6.2	11.1	17.4	25.1	34.2	44.6	56.5	69.8	84.4
33	2.9	6.6	11.8	18.5	26.7	36.3	47.5	60.1	74.2	89.8
34	3.1	7.0	12.6	19.7	28.3	38.6	50.4	63.8	78.8	95.3
35	3.3	7.5	13.3	20.8	30.0	40.9	53.4	67.6	83.5	101.0
36	3.5	7.9	14.1	22.0	31.8	43.2	56.5	71.5	88.3	106.9
37	3.7	8.4	14.9	23.3	33.6	45.7	59.7	75.6	93.3	112.9
38	3.9	8.8	15.7	24.6	35.4	48.2	63.0	79.7	98.4	119.1
39	4.1	9.3	16.5	25.9	37.3	50.8	66.3	83.9	103.6	125.4
40	4.3	9.8	17.4	27.2	39.2	53.4	69.8	88.3	109.0	131.9
41	4.5	10.3	18.3	28.6	41.2	56.1	73.3	92.8	114.6	138.6
42	4.8	10.8	19.2	30.0	43.2	58.9	76.9	97.4	120.2	145.5
43	5.0	11.3	20.1	31.5	45.3	61.7	80.6	102.1	126.0	152.5
44	5.2	11.8	21.1	32.9	47.5	64.6	84.4	106.9	131.9	159.7
45	5.5	12.4	22.0	34.5	49.7	67.6	88.3	111.8	138.0	167.0
46	5.7	12.9	23.0	36.0	51.9	70.6	92.3	116.8	144.2	174.5
47	6.0	13.5	24.0	37.5	54.2	73.7	96.3	121.9	150.6	182.2
48	6.2	14.1	25.1	39.2	56.5	76.9	100.5	127.2	157.0	190.0
49	6.5	14.7	26.1	40.9	58.9	80.2	104.7	132.5	163.6	198.0
50	6.8	15.3	27.2	42.6	61.3	83.5	109.0	138.0	170.4	206.2
51	7.0	15.9	28.3	44.3	63.8	86.8	113.4	143.6	177.3	214.5
52	7.3	16.5	29.4	46.0	66.3	90.3	117.9	149.3	184.3	223.0
53	7.6	17.2	30.6	47.8	68.9	93.8	122.5	155.1	191.5	231.7
54	7.9	17.8	31.8	49.7	71.5	97.4	127.2	161.0	198.8	240.5
55	8.2	18.5	32.9	51.5	74.2	101.0	131.9	167.0	206.2	249.5
56	8.5	19.2	34.2	53.4	76.9	104.7	136.8	173.1	213.8	258.7
57	8.8	19.9	35.4	55.3	79.7	108.5	141.7	179.4	221.5	268.0
58	9.1	20.6	36.6	57.3	82.5	112.3	146.7	185.7	229.3	277.5
59	9.4	21.3	37.9	59.3	85.4	116.2	151.8	192.2	237.3	287.1
60	9.8	22.0	39.2	61.3	88.3	120.2	157.0	198.8	245.4	296.9

due to log stringers in foot kips

LENGTH (FT)								
60	65	70	75	80	85	90	95	100
9.8	11.5	13.3	15.3	17.4	19.7	22.0	24.6	27.2
11.8	13.9	16.1	18.5	21.1	23.8	26.7	29.7	32.9
14.1	16.5	19.2	22.0	25.1	28.3	31.8	35.4	39.2
16.5	19.4	22.5	25.9	29.4	33.2	37.3	41.5	46.0
19.2	22.5	26.1	30.0	34.2	38.6	43.2	48.2	53.4
22.0	25.9	30.0	34.5	39.2	44.3	49.7	55.3	61.3
25.1	29.4	34.2	39.2	44.6	50.4	56.5	63.0	69.8
28.3	33.2	38.6	44.3	50.4	56.9	63.8	71.1	78.8
31.8	37.3	43.2	49.7	56.5	63.8	71.5	79.7	88.3
35.4	41.5	48.2	55.3	63.0	71.1	79.7	88.8	98.4
39.2	46.0	53.4	61.3	69.8	78.8	88.3	98.4	109.0
43.2	50.8	58.9	67.6	76.9	86.8	97.4	108.5	120.2
47.5	55.7	64.6	74.2	84.4	95.3	106.9	119.1	131.9
51.9	60.9	70.6	81.1	92.3	104.2	116.8	130.1	144.2
56.5	66.3	76.9	88.3	100.5	113.4	127.2	141.7	157.0
61.3	72.0	83.5	95.8	109.0	123.1	138.0	153.8	170.4
66.3	77.8	90.3	103.6	117.9	133.1	149.3	166.3	184.3
71.5	83.9	97.4	111.8	127.2	143.6	161.0	179.4	198.8
76.9	90.3	104.7	120.2	136.8	154.4	173.1	192.9	213.8
82.5	96.8	112.3	129.0	146.7	165.7	185.7	206.9	229.3
88.3	103.6	120.2	138.0	157.0	177.3	198.8	221.5	245.4
94.3	110.7	128.4	147.4	167.7	189.3	212.2	236.5	262.0
100.5	117.9	136.8	157.0	178.7	201.7	226.1	252.0	279.2
106.9	125.4	145.5	167.0	190.0	214.5	240.5	268.0	296.9
113.4	133.1	154.4	177.3	201.7	227.7	255.3	284.5	315.2
120.2	141.1	163.6	187.9	213.8	241.3	270.5	301.4	334.0
127.2	149.3	173.1	198.8	226.1	255.3	286.2	318.9	353.4
134.4	157.7	182.9	210.0	238.9	269.7	302.4	336.9	373.3
141.7	166.3	192.9	221.5	252.0	284.5	318.9	355.3	393.7
149.3	175.2	203.2	233.3	265.4	299.6	335.9	374.3	414.7
157.0	184.3	213.8	245.4	279.2	315.2	353.4	393.7	436.3
165.0	193.6	224.6	257.8	293.3	331.2	371.3	413.7	458.4
173.1	203.2	235.7	270.5	307.8	347.5	389.6	434.1	481.0
181.5	213.0	247.0	283.6	322.7	364.3	408.4	455.0	504.2
190.0	223.0	258.7	296.9	337.8	381.4	427.6	476.4	527.9
198.8	233.3	270.5	310.6	353.4	398.9	447.3	498.3	552.2
207.7	243.8	282.7	324.5	369.3	416.9	467.4	520.7	577.0
216.8	254.5	295.1	338.8	385.5	435.2	487.9	543.6	602.4
226.1	265.4	307.8	353.4	402.1	453.9	508.9	567.0	628.3
235.7	276.6	320.8	368.3	419.0	473.0	530.3	590.9	654.7
245.4	288.0	334.0	383.4	436.3	492.5	552.2	615.2	681.7
255.3	299.6	347.5	398.9	453.9	512.4	574.5	640.1	709.3
265.4	311.5	361.3	414.7	471.9	532.7	597.2	665.5	737.4
275.7	323.6	375.3	430.8	490.2	553.4	620.4	691.3	766.0
286.2	335.9	389.6	447.3	508.9	574.5	644.1	717.6	795.2
296.9	348.5	404.2	464.0	527.9	596.0	668.2	744.5	824.9
307.8	361.3	419.0	481.0	547.3	617.8	692.7	771.8	855.2
318.9	374.3	434.1	498.3	567.0	640.1	717.6	799.6	886.0
330.2	387.5	449.5	516.0	587.1	662.8	743.0	827.9	917.3
341.7	401.0	465.1	533.9	607.5	685.8	768.9	856.7	949.2
353.4	414.7	481.0	552.2	628.3	709.3	795.2	886.0	981.7

Table 4. Bending moments due to

DIA	SPAN									
	10	15	20	25	30	35	40	45	50	55
10	1.2	2.8	5.0	7.8	11.2	15.3	20.0	25.3	31.2	37.8
11	1.3	3.0	5.5	8.5	12.3	16.8	22.0	27.8	34.3	41.5
12	1.5	3.3	6.0	9.3	13.5	18.3	24.0	30.3	37.5	45.3
13	1.6	3.6	6.5	10.1	14.6	19.9	26.0	32.9	40.6	49.1
14	1.7	3.9	7.0	10.9	15.7	21.4	28.0	35.4	43.7	52.9
15	1.8	4.2	7.5	11.7	16.8	22.9	30.0	37.9	46.8	56.7
16	2.0	4.5	8.0	12.5	18.0	24.5	32.0	40.5	50.0	60.5
17	2.1	4.7	8.5	13.2	19.1	26.0	34.0	43.0	53.1	64.2
18	2.2	5.0	9.0	14.0	20.2	27.5	36.0	45.5	56.2	68.0
19	2.3	5.3	9.5	14.8	21.3	29.0	38.0	48.0	59.3	71.8
20	2.5	5.6	10.0	15.6	22.5	30.6	40.0	50.6	62.5	75.6
21	2.6	5.9	10.5	16.4	23.6	32.1	42.0	53.1	65.6	79.4
22	2.7	6.1	11.0	17.1	24.7	33.6	44.0	55.6	68.7	83.1
23	2.8	6.4	11.5	17.9	25.8	35.2	46.0	58.2	71.8	86.9
24	3.0	6.7	12.0	18.7	27.0	36.7	48.0	60.7	75.0	90.7
25	3.1	7.0	12.5	19.5	28.1	38.2	50.0	63.2	78.1	94.5
26	3.2	7.3	13.0	20.3	29.2	39.8	52.0	65.8	81.2	98.3
27	3.3	7.5	13.5	21.0	30.3	41.3	54.0	68.3	84.3	102.0
28	3.5	7.8	14.0	21.8	31.5	42.8	56.0	70.8	87.5	105.8
29	3.6	8.1	14.5	22.6	32.6	44.4	58.0	73.4	90.6	109.6
30	3.7	8.4	15.0	23.4	33.7	45.9	60.0	75.9	93.7	113.4
31	3.8	8.7	15.5	24.2	34.8	47.4	62.0	78.4	96.8	117.2
32	4.0	9.0	16.0	25.0	36.0	49.0	64.0	81.0	100.0	121.0
33	4.1	9.2	16.5	25.7	37.1	50.5	66.0	83.5	103.1	124.7
34	4.2	9.5	17.0	26.5	38.2	52.0	68.0	86.0	106.2	128.5
35	4.3	9.8	17.5	27.3	39.3	53.5	70.0	88.5	109.3	132.3
36	4.5	10.1	18.0	28.1	40.5	55.1	72.0	91.1	112.5	136.1
37	4.6	10.4	18.5	28.9	41.6	56.6	74.0	93.6	115.6	139.9
38	4.7	10.6	19.0	29.6	42.7	58.1	76.0	96.1	118.7	143.6
39	4.8	10.9	19.5	30.4	43.8	59.7	78.0	98.7	121.8	147.4
40	5.0	11.2	20.0	31.2	45.0	61.2	80.0	101.2	125.0	151.2
41	5.1	11.5	20.5	32.0	46.1	62.7	82.0	103.7	128.1	155.0
42	5.2	11.8	21.0	32.8	47.2	64.3	84.0	106.3	131.2	158.8
43	5.3	12.0	21.5	33.5	48.3	65.8	86.0	108.8	134.3	162.5
44	5.5	12.3	22.0	34.3	49.5	67.3	88.0	111.3	137.5	166.3
45	5.6	12.6	22.5	35.1	50.6	68.9	90.0	113.9	140.6	170.1
46	5.7	12.9	23.0	35.9	51.7	70.4	92.0	116.4	143.7	173.9
47	5.8	13.2	23.5	36.7	52.8	71.9	94.0	118.9	146.8	177.7
48	6.0	13.5	24.0	37.5	54.0	73.5	96.0	121.5	150.0	181.5
49	6.1	13.7	24.5	38.2	55.1	75.0	98.0	124.0	153.1	185.2
50	6.2	14.0	25.0	39.0	56.2	76.5	100.0	126.5	156.2	189.0
51	6.3	14.3	25.5	39.8	57.3	78.0	102.0	129.0	159.3	192.8
52	6.5	14.6	26.0	40.6	58.5	79.6	104.0	131.6	162.5	196.6
53	6.6	14.9	26.5	41.4	59.6	81.1	106.0	134.1	165.6	200.4
54	6.7	15.1	27.0	42.1	60.7	82.6	108.0	136.6	168.7	204.1
55	6.8	15.4	27.5	42.9	61.8	84.2	110.0	139.2	171.8	207.9
56	7.0	15.7	28.0	43.7	63.0	85.7	112.0	141.7	175.0	211.7
57	7.1	16.0	28.5	44.5	64.1	87.2	114.0	144.2	178.1	215.5
58	7.2	16.3	29.0	45.3	65.2	88.8	116.0	146.8	181.2	219.3
59	7.3	16.5	29.5	46.0	66.3	90.3	118.0	149.3	184.3	223.0
60	7.5	16.8	30.0	46.8	67.5	91.8	120.0	151.8	187.5	226.8

12 inches of rock fill in foot-kips

LENGTH (FT)								
60	65	70	75	80	85	90	95	100
45.0	52.8	61.2	70.3	80.0	90.3	101.2	112.8	125.0
49.5	58.0	67.3	77.3	88.0	99.3	111.3	124.0	137.5
54.0	63.3	73.5	84.3	96.0	108.3	121.5	135.3	150.0
58.5	68.6	79.6	91.4	104.0	117.4	131.6	146.6	162.5
63.0	73.9	85.7	98.4	112.0	126.4	141.7	157.9	175.0
67.5	79.2	91.8	105.4	120.0	135.4	151.8	169.2	187.5
72.0	84.5	98.0	112.5	128.0	144.5	162.0	180.5	200.0
76.5	89.7	104.1	119.5	136.0	153.5	172.1	191.7	212.5
81.0	95.0	110.2	126.5	144.0	162.5	182.2	203.0	225.0
85.5	100.3	116.3	133.5	152.0	171.5	192.3	214.3	237.5
90.0	105.6	122.5	140.6	160.0	180.6	202.5	225.6	250.0
94.5	110.9	128.6	147.6	168.0	189.6	212.6	236.9	262.5
99.0	116.1	134.7	154.6	176.0	198.6	222.7	248.1	275.0
103.5	121.4	140.8	161.7	184.0	207.7	232.8	259.4	287.5
108.0	126.7	147.0	168.7	192.0	216.7	243.0	270.7	300.0
112.5	132.0	153.1	175.7	200.0	225.7	253.1	282.0	312.5
117.0	137.3	159.2	182.8	208.0	234.8	263.2	293.3	325.0
121.5	142.5	165.3	189.8	216.0	243.8	273.3	304.5	337.5
126.0	147.8	171.5	196.8	224.0	252.8	283.5	315.8	350.0
130.5	153.1	177.6	203.9	232.0	261.9	293.6	327.1	362.5
135.0	158.4	183.7	210.9	240.0	270.9	303.7	338.4	375.0
139.5	163.7	189.8	217.9	248.0	279.9	313.8	349.7	387.5
144.0	169.0	196.0	225.0	256.0	289.0	324.0	361.0	400.0
148.5	174.2	202.1	232.0	264.0	298.0	334.1	372.2	412.5
153.0	179.5	208.2	239.0	272.0	307.0	344.2	383.5	425.0
157.5	184.8	214.3	246.0	280.0	316.0	354.3	394.8	437.5
162.0	190.1	220.5	253.1	288.0	325.1	364.5	406.1	450.0
166.5	195.4	226.6	260.1	296.0	334.1	374.6	417.4	462.5
171.0	200.6	232.7	267.1	304.0	343.1	384.7	428.6	475.0
175.5	205.9	238.8	274.2	312.0	352.2	394.8	439.9	487.5
180.0	211.2	245.0	281.2	320.0	361.2	405.0	451.2	500.0
184.5	216.5	251.1	288.2	328.0	370.2	415.1	462.5	512.5
189.0	221.8	257.2	295.3	336.0	379.3	425.2	473.8	525.0
193.5	227.0	263.3	302.3	344.0	388.3	435.3	485.0	537.5
198.0	232.3	269.5	309.3	352.0	397.3	445.5	496.3	550.0
202.5	237.6	275.6	316.4	360.0	406.4	455.6	507.6	562.5
207.0	242.9	281.7	323.4	368.0	415.4	465.7	518.9	575.0
211.5	248.2	287.8	330.4	376.0	424.4	475.8	530.2	587.5
216.0	253.5	294.0	337.5	384.0	433.5	486.0	541.5	600.0
220.5	258.7	300.1	344.5	392.0	442.5	496.1	552.7	612.5
225.0	264.0	306.2	351.5	400.0	451.5	506.2	564.0	625.0
229.5	269.3	312.3	358.5	408.0	460.5	516.3	575.3	637.5
234.0	274.6	318.5	365.6	416.0	469.6	526.5	586.6	650.0
238.5	279.9	324.6	372.6	424.0	478.6	536.6	597.9	662.5
243.0	285.1	330.7	379.6	432.0	487.6	546.7	609.1	675.0
247.5	290.4	336.8	386.7	440.0	496.7	556.8	620.4	687.5
252.0	295.7	343.0	393.7	448.0	505.7	567.0	631.7	700.0
256.5	301.0	349.1	400.7	456.0	514.7	577.1	643.0	712.5
261.0	306.3	355.2	407.8	464.0	523.8	587.2	654.3	725.0
265.5	311.5	361.3	414.8	472.0	532.8	597.3	665.5	737.5
270.0	316.8	367.5	421.8	480.0	541.8	607.5	676.8	750.0

Table 5. Allowable bending moments

DIA	ALLOWABLE STRESS								
	1000	1100	1200	1300	1400	1500	1600	1700	1800
10	8.	8.	9.	10.	11.	12.	13.	13.	14.
11	10.	11.	13.	14.	15.	16.	17.	18.	19.
12	14.	15.	16.	18.	19.	21.	22.	24.	25.
13	17.	19.	21.	23.	25.	26.	28.	30.	32.
14	22.	24.	26.	29.	31.	33.	35.	38.	40.
15	27.	30.	33.	35.	38.	41.	44.	46.	49.
16	33.	36.	40.	43.	46.	50.	53.	56.	60.
17	40.	44.	48.	52.	56.	60.	64.	68.	72.
18	47.	52.	57.	62.	66.	71.	76.	81.	85.
19	56.	61.	67.	72.	78.	84.	89.	95.	101.
20	65.	71.	78.	85.	91.	98.	104.	111.	117.
21	75.	83.	90.	98.	106.	113.	121.	128.	136.
22	87.	95.	104.	113.	121.	130.	139.	148.	156.
23	99.	109.	119.	129.	139.	149.	159.	169.	179.
24	113.	124.	135.	147.	158.	169.	180.	192.	203.
25	127.	140.	153.	166.	178.	191.	204.	217.	230.
26	143.	158.	172.	186.	201.	215.	230.	244.	258.
27	161.	177.	193.	209.	225.	241.	257.	273.	289.
28	179.	197.	215.	233.	251.	269.	287.	305.	323.
29	199.	219.	239.	259.	279.	299.	319.	339.	359.
30	220.	242.	265.	287.	309.	331.	353.	375.	397.
31	243.	268.	292.	316.	341.	365.	389.	414.	438.
32	268.	294.	321.	348.	375.	402.	428.	455.	482.
33	294.	323.	352.	382.	411.	441.	470.	499.	529.
34	321.	353.	385.	418.	450.	482.	514.	546.	578.
35	350.	385.	420.	456.	491.	526.	561.	596.	631.
36	381.	419.	458.	496.	534.	572.	610.	648.	687.
37	414.	455.	497.	538.	580.	621.	663.	704.	745.
38	448.	493.	538.	583.	628.	673.	718.	763.	808.
39	485.	533.	582.	630.	679.	727.	776.	825.	873.
40	523.	575.	628.	680.	733.	785.	837.	890.	942.
41	563.	620.	676.	733.	789.	845.	902.	958.	1014.
42	606.	666.	727.	787.	848.	909.	969.	1030.	1091.
43	650.	715.	780.	845.	910.	975.	1040.	1105.	1170.
44	696.	766.	836.	905.	975.	1045.	1115.	1184.	1254.
45	745.	820.	894.	969.	1043.	1118.	1192.	1267.	1341.
46	796.	875.	955.	1035.	1114.	1194.	1274.	1353.	1433.
47	849.	934.	1019.	1104.	1189.	1274.	1359.	1443.	1528.
48	904.	995.	1085.	1176.	1266.	1357.	1447.	1538.	1628.
49	962.	1058.	1155.	1251.	1347.	1443.	1540.	1636.	1732.
50	1022.	1124.	1227.	1329.	1431.	1533.	1636.	1738.	1840.
51	1085.	1193.	1302.	1410.	1519.	1627.	1736.	1844.	1953.
52	1150.	1265.	1380.	1495.	1610.	1725.	1840.	1955.	2070.
53	1217.	1339.	1461.	1583.	1705.	1826.	1948.	2070.	2192.
54	1288.	1417.	1545.	1674.	1803.	1932.	2061.	2190.	2318.
55	1361.	1497.	1633.	1769.	1905.	2041.	2177.	2313.	2450.
56	1436.	1580.	1724.	1867.	2011.	2155.	2298.	2442.	2586.
57	1515.	1666.	1818.	1969.	2121.	2272.	2424.	2575.	2727.
58	1596.	1755.	1915.	2075.	2234.	2394.	2554.	2713.	2873.
59	1680.	1848.	2016.	2184.	2352.	2520.	2688.	2856.	3024.
60	1767.	1943.	2120.	2297.	2474.	2650.	2827.	3004.	3180.

for log stringers in foot-kips

LEVEL (PSI)							
1900	2000	2100	2200	2300	2400	2500	2600
15.	16.	17.	17.	18.	19.	20.	21.
20.	21.	22.	23.	25.	26.	27.	28.
26.	28.	29.	31.	32.	33.	35.	36.
34.	35.	37.	39.	41.	43.	44.	46.
42.	44.	47.	49.	51.	53.	56.	58.
52.	55.	57.	60.	63.	66.	69.	71.
63.	67.	70.	73.	77.	80.	83.	87.
76.	80.	84.	88.	92.	96.	100.	104.
90.	95.	100.	104.	109.	114.	119.	124.
106.	112.	117.	123.	129.	134.	140.	145.
124.	130.	137.	143.	150.	157.	163.	170.
143.	151.	159.	166.	174.	181.	189.	196.
165.	174.	182.	191.	200.	209.	217.	226.
189.	199.	209.	218.	228.	238.	248.	258.
214.	226.	237.	248.	260.	271.	282.	294.
242.	255.	268.	281.	294.	306.	319.	332.
273.	287.	301.	316.	330.	345.	359.	373.
305.	322.	338.	354.	370.	386.	402.	418.
341.	359.	377.	395.	413.	431.	448.	466.
379.	399.	419.	438.	458.	478.	498.	518.
419.	441.	463.	485.	508.	530.	552.	574.
463.	487.	511.	536.	560.	584.	609.	633.
509.	536.	562.	589.	616.	643.	670.	697.
558.	588.	617.	646.	676.	705.	735.	764.
610.	643.	675.	707.	739.	771.	803.	836.
666.	701.	736.	771.	806.	841.	876.	912.
725.	763.	801.	839.	877.	916.	954.	992.
787.	828.	870.	911.	953.	994.	1036.	1077.
852.	897.	942.	987.	1032.	1077.	1122.	1167.
922.	970.	1019.	1067.	1116.	1164.	1213.	1261.
994.	1047.	1099.	1151.	1204.	1256.	1309.	1361.
1071.	1127.	1184.	1240.	1296.	1353.	1409.	1466.
1151.	1212.	1272.	1333.	1394.	1454.	1515.	1575.
1235.	1300.	1365.	1431.	1496.	1561.	1626.	1691.
1324.	1393.	1463.	1533.	1602.	1672.	1742.	1811.
1416.	1491.	1565.	1640.	1714.	1789.	1863.	1938.
1513.	1592.	1672.	1751.	1831.	1911.	1990.	2070.
1613.	1698.	1783.	1868.	1953.	2038.	2123.	2208.
1719.	1809.	1900.	1990.	2080.	2171.	2261.	2352.
1828.	1925.	2021.	2117.	2213.	2310.	2406.	2502.
1943.	2045.	2147.	2249.	2352.	2454.	2556.	2658.
2061.	2170.	2279.	2387.	2496.	2604.	2713.	2821.
2185.	2300.	2415.	2530.	2645.	2760.	2875.	2990.
2314.	2435.	2557.	2679.	2801.	2923.	3044.	3166.
2447.	2576.	2705.	2834.	2962.	3091.	3220.	3349.
2586.	2722.	2858.	2994.	3130.	3266.	3402.	3539.
2729.	2873.	3017.	3160.	3304.	3448.	3591.	3735.
2878.	3030.	3181.	3333.	3484.	3636.	3787.	3939.
3032.	3192.	3352.	3511.	3671.	3831.	3990.	4150.
3192.	3360.	3528.	3696.	3864.	4032.	4200.	4368.
3357.	3534.	3711.	3887.	4064.	4241.	4417.	4594.

Table 6. Maximum live-load bending moments in foot-kips

SPAN LENGTH (ft)	VEHICLE TYPE								
	AASHTO LOADS (See figure 2)				R-10 DESIGN LOADS (See figure 3)				
	Type 3	Type 3S2	Type 3-3	HS20	U54	U80	U102	L70	L90
10	51	51	45	80	72	111	168	117	150
15	90	90	79	120	130	201	304	263	338
20	130	130	113	160	189	292	441	438	563
25	169	174	148	207	248	383	580	613	788
30	212	224	183	282	324	500	719	788	1,013
35	268	274	232	361	430	662	858	963	1,238
40	326	324	284	450	545	841	998	1,138	1,463
45	383	374	336	539	670	1,028	1,137	1,313	1,688
50	440	448	388	628	804	1,225	1,277	1,488	1,913
55	497	536	449	717	939	1,423	1,417	1,663	2,138
60	555	624	534	807	1,073	1,622	1,556	1,838	2,363
65	612	713	620	896	1,207	1,820	1,696	2,013	2,588
70	669	801	706	986	1,342	2,019	1,836	2,188	2,813
75	727	890	798	1,075	1,476	2,218	1,976	2,363	3,038
80	784	979	889	1,165	1,611	2,417	2,116	2,538	3,263
85	842	1,068	982	1,255	1,746	2,617	2,398	2,713	3,488
90	899	1,158	1,074	1,344	1,880	2,816	2,668	2,888	3,712
95	956	1,247	1,166	1,434	2,015	3,015	2,906	3,063	3,938
100	1,014	1,336	1,259	1,524	2,150	3,215	3,145	3,238	4,163

Note: The maximum moment occurs at the wheel nearest to the $\bar{C}_L$ of the span when the position of the truck is such that the $\bar{C}_L$ of the span is equidistant from that wheel and the resultant of all wheel loads.

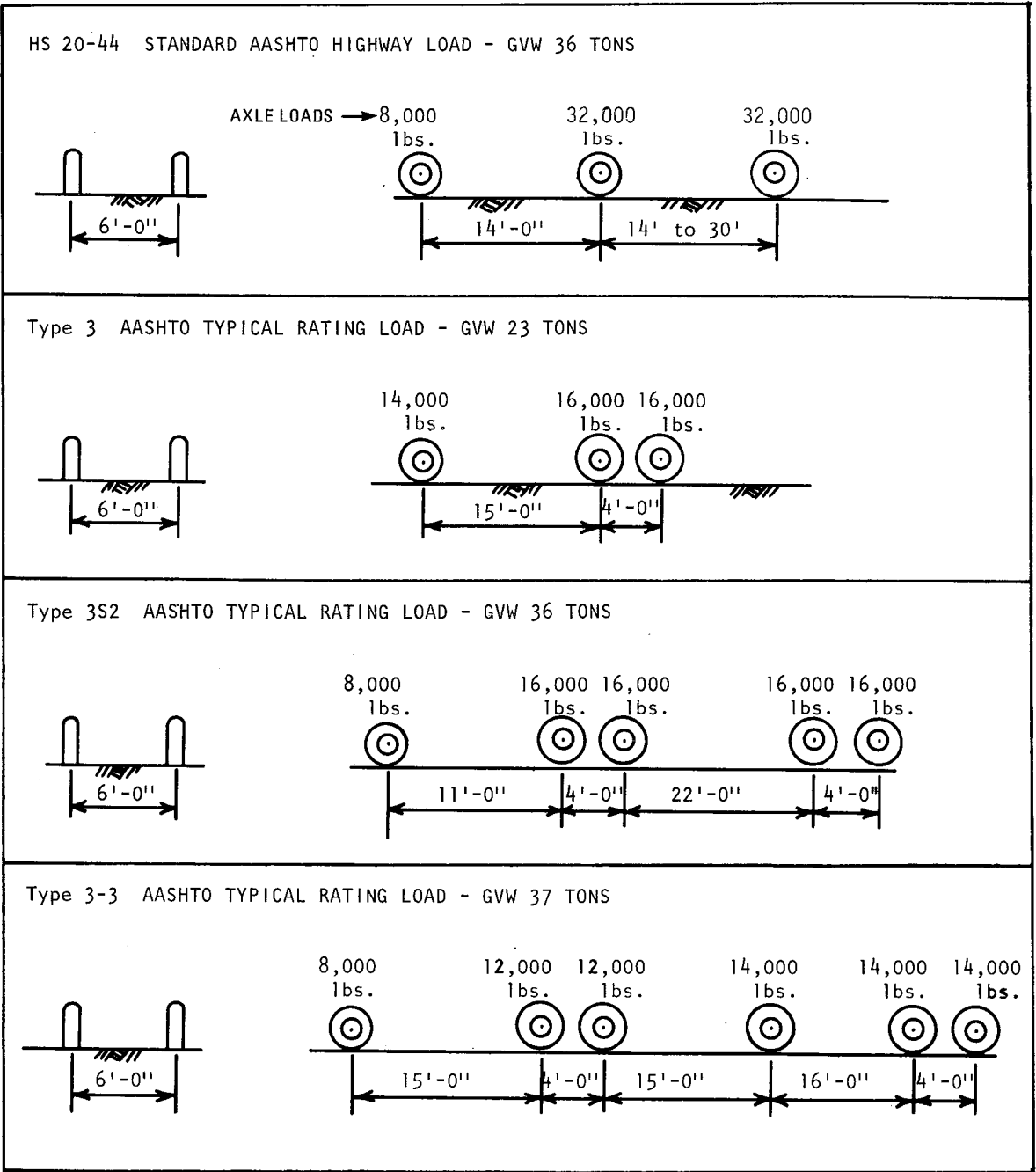


Figure 2. Standard AASHTO bridge, live-load.

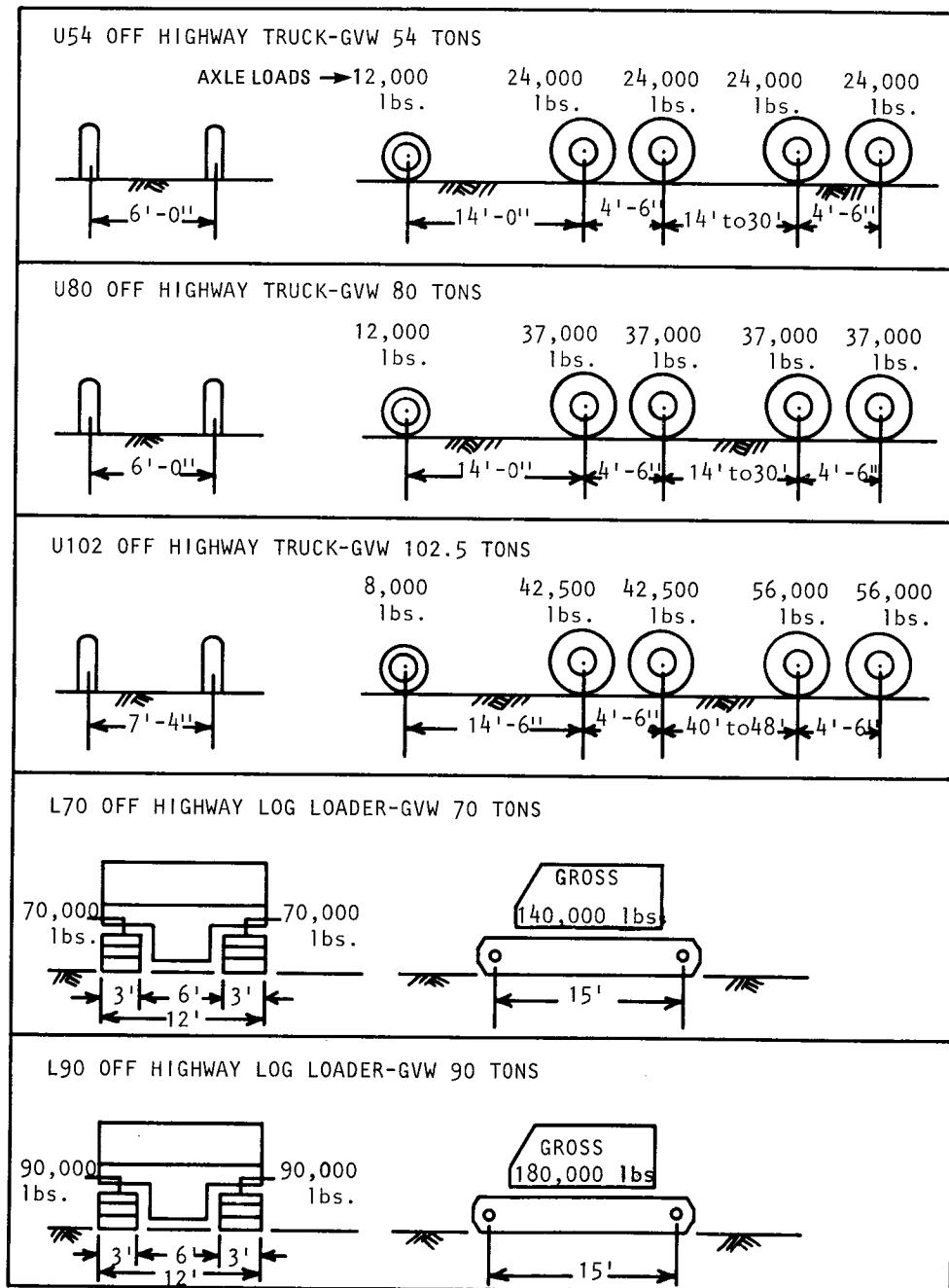


Figure 3. Standard bridge design, live-load.

Table 7. Approximate sitka spruce stringer diameters¹ required for design loads

SPAN LENGTH (ft)	VEHICLE TYPE			
	HS20	U54	U80	U102
10	18	18	18	18
15	18	18	19	21
20	18	19	21	23
25	19	20	22	25
30	21	22	25	27
35	23	24	27	29
40	24	26	29	31
45	27	28	32	33
50	28	30	34	34
55	30	32	36	36
60	32	34	38	38
65	34	36	40	40
70	36	38	42	42
75	37	40	44	43
80	39	42	46	45
85	41	44	49	47
90	43	46	51	50
95	45	48	53	52
100	47	50	55	54

¹The diameters given are in inches, representing average midspan diameters. Required diameters will vary with the depth of rock surfacing. Depths of rock used to calculate the table are:

spans to 20 feet—12 inches
spans of 20 feet to 35 feet—9 inches
spans over 35 feet—6 inches.

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4. *Manual for Maintenance Inspection of Bridges*, American Association of State Highway and Transportation Officials, second edition, 1974.
5. *Native Log Stringer Bridges*, Timothy Windle, USDA, Forest Service, R-10, Juneau, Alaska, September 1973 (unpublished).
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ANALYSIS AND LOAD-RATING OF NATIVE LOG STRINGER BRIDGES

Frank W. Muchmore, P.E.
Region 10

Author's Note

This HP-65 Program was developed following the procedures outlined in the R-10 "Design Guide for Native Log Stringer Bridges" to load-rate this type of bridge.

Input data required are found in the tables included in the design guide. A separate program card can be inserted following execution of the program to output the load-rating for inventory or operating ratings for the AASHTO Type 3, Type 3S2, and Type 3-3 rating vehicles.



Page 1 of 4

KEY ENTRY	CODE SHOWN	COMMENTS
LBL	23	
A	11	
R/S	84	1) DLM Log—Enter 3) Opr.Allow.Mom.—Enter 2) DLM Rock—Enter 4) Inv.Allow.Mom.—R/S
STO 1	33 01	Inv. Allow. Mom.
g ↓	35 08	
STO 2	33 02	Opr. Allow. Mom.
g ↓	35 08	
STO 3	33 03	DLM Rock Deck
g ↓	35 08	
10 STO 4	33 04	DLM Log.
R/S	84	1) Depth Rock Deck (inches) —Enter 2) Distribution Factor — R/S
STO 5	33 05	Distribution Factor
g ↓	35 08	
Enter ↑	41	Depth deck
1	01	
2	02	
÷	81	Depth deck ÷ 12
RCL 3	34 03	DLM for 12" deck
X	71	X deck ratio
20 RCL 4	34 04	
+	61	
STO 4	33 04	DLM Log + DLM Deck
RCL 2	34 02	Opr. Allow. Mom.
Enter ↑	41	
RCL 4	34 04	DLM Log + DLM Deck
—	51	Opr. Allow. Mom. — (DLM Log + Deck)
Enter ↑	41	
RCL 5	34 05	Dist. factor
÷	81	
30 STO 2	33 02	Total Avail. LLM — Operating
RCL 1	34 01	Inv. Allow. Mom.
Enter ↑	41	
RCL 4	34 04	DLM Log + DLM Deck
—	51	
Enter ↑	41	Inv. Allow. M. — (DLM Log + Deck)
RCL 5	34 05	Dist. Factor
÷	81	
STO 1	33 01	Total Avail. LLM — Inventory
R/S	84	1) LLM—Type 3—Enter 3) LLM—Type 3-3—R/S 2) LLM—Type 3S2—Enter
40 STO 5	33 05	LLM — Type 3-3
g ↓	35 08	
STO 4	33 04	LLM — Type 3S2
g ↓	35 08	
STO 3	33 03	LLM — Type 3
RCL 2	34 02	Opr. Allow. Mom.
Enter ↑	41	
RCL 3	34 03	LLM — Type 3
÷	81	
2	02	
50 3	03	

Avail. LLM - Op.

Avail. LLM - Inv.

[illegible]

REGISTERS	
R ₁	_____
R ₂	_____
R ₃	_____
R ₄	_____
R ₅	_____
R ₆	_____
R ₇	_____
R ₈	_____
R ₉	_____
LABELS	
A	_____
B	_____
C	_____
D	_____
E	_____
0	_____
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____
9	_____
FLAGS	
1	_____
2	_____

9320-0615

TO RECORD PROGRAM INSERT MAGNETIC CARD WITH SWITCH SET AT W:PRGM

Figure 1. HP-65 Program Form.



Page 2 of 4

Date 9/6/74

[illegible]

Figure 2. HP-65 User Instruction Form.

Page 3 of 4[illegible]

TO RECORD PROGRAM INSERT MAGNETIC CARD WITH SWITCH SET AT W/PRGM.

Figure 3. HP-65 Program Form.

WASHINGTON OFFICE NEWS

OPERATIONS

Harold L. Strickland
Assistant Director

SELF-STUDY COURSE BOOKS

We are reprinting an "emergency supply" of the four Self-Study Course books, EM-7110-1, 1 a, 1 b, and 1 c. After this reprint is distributed, the existing material will be updated, and new texts for the remaining categories will be written. A task force came to Washington in May to develop a sample text for all Regions to use as a guide in completing the assigned text material. The intent is to have study material and JPR's printed and distributed by the spring of 1977.

CERTIFICATION EXAMINATIONS

This spring, you received four revised certification examinations: Sampling and Testing; Advanced Administration, Public Works; Administration and Advanced Administration, Timber Sales (formerly referred to as "Timber Purchaser" certification). These exams were written in multiple-choice format, which eliminates the necessity of grading essay-type questions and permits grading by either Hewlett-Packard or Wang Equipment. Machine grading can give immediate feedback of the score achieved, and which JPR's need further study.

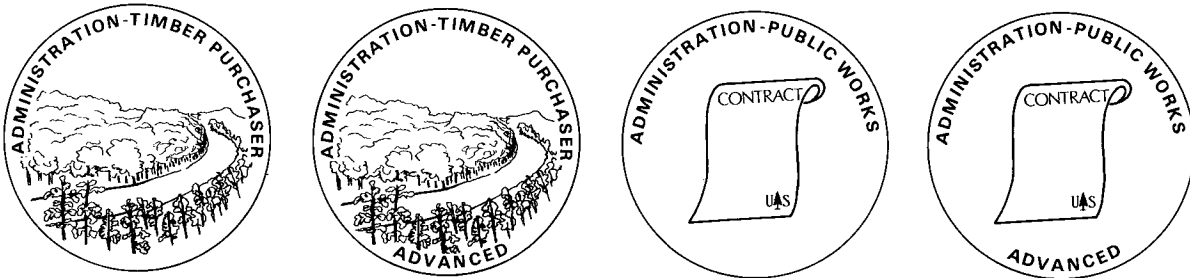
The certification examinations for the other categories are being rewritten presently, and will be distributed when they are completed.

JPR BOOK

Your "Little Green JPR Book" will take on a new look when it is revised. The new edition will be part of the handbook system. An earlier survey indicated that few, if any, of you carried the JPR's in your pocket, and that the standard Forest Service handbook size would pack well in a briefcase with contract documents of similar size. We are planning to distribute the revised JPR's in the fall.

CERTIFICATION SYMBOLS

A new supply of certification symbols was printed this spring. In addition to the ten standard symbols, four new ones were added. They are: Administration and Advanced Administration, Timber Sales (formerly referred to as "Timber Purchaser" certification); and Administration and Advanced Administration, Public Works. The symbols are shown below:



TECHNOLOGICAL IMPROVEMENTS

Heyward T. Taylor
Assistant Director

SERVICE EQUIPMENT DEVELOPMENT & TEST PROGRAM

The protection and management of forests and wildlands is a role of many challenges. To meet these challenges, the Forest Service provides the managers and field personnel with equipment to enable forest work to be performed more efficiently, at less cost, and with minimum hazard to workers, users, and the forest. In their role of managing and utilizing forest resources, the managers and field personnel make known their equipment needs through Regional boards, ad hoc committees, workshops, and, often, in the form of employee suggestions. These ideas and suggestions then become projects in the Service-wide Equipment Development and Test Program carried out by the Equipment Development Centers at Missoula, Mont., and San Dimas, Calif., and in the Southern Region by an Equipment Development Engineer at Atlanta, Ga. The program encompasses development, test, analysis, standardization, and evaluation of all types of equipment and materials.

To keep the field informed on the progress of on-going projects at the Equipment Development Centers, one of the Centers will be featured in *Field Notes* on a quarterly basis. San Dimas is highlighted in this issue.

FORESTLAND RESIDUES MACHINE

The San Dimas Slash Machine, featured in *Field Notes*, Vol. 8 No. 3, March 1976, has appropriately been redesignated the Forestland Residues Machine. The total machine has a reduction head (cutter) that was designed and fabricated at San Dimas and mounted on a Hydro-Ax 1000 prime mover. The reduction head is a direct result of the Center's development program for a machine to accomplish timber-stand improvement work and to treat both thinning and logging residues. The prototype has been field-tested in California and Oregon on the Tahoe, Plumas, and Deschutes National Forests. Most of the data gathered in the San Dimas Slash Lab during the field testing has been confirmed under actual working conditions.

In July, the new reduction head design was presented to industry for competitive bid. The new reduction head will be mounted on the Hydro-Ax 1000 and used on the Deschutes National Forest; delivery is expected to the Forest Service in December 1976. The Center's engineers will monitor the machine and use the data collected to encourage industry to furnish commercial versions of the reduction head.

RECREATION FACILITIES EQUIPMENT

In February 1976, a special report entitled "Vault Toilets . . . design and maintenance considerations" was published. Another report that considers all aspects of vault toilets—construction materials, venting techniques, biological and chemical additives, and vault inventories—will be published soon.

The Center is continuing its evaluations on the oil-recirculating toilets (*Equip Tips* 2300, August 1975, SDEDC), low-volume water flush toilets, plastic picnic table tops and bench tops (*Equip Tips* 2300, July 1975, SDEDC) and vault toilet venting modifications. Also, the watersure chlorinators, models 050 and 101, are currently being evaluated for low-pressure, low-flow, remote-type nonelectrical systems. In addition, two compost-type toilets, Clivus Multrum and Toa-throne, are being evaluated for possible use in lower visitor-use wilderness sites. Unfortunately, it requires years to determine if the compost principle will be acceptable for the intended application.

FIRE AND AVIATION MANAGEMENT

The Center's Fire Management Staff has spent considerable time and effort in the field of retardants and retardant-related work this year. The main thrust has been on the proposed 1977 retardant specification. Work has been completed on new requirements and test procedures on health and safety, color, spoilage, corrosion, and pumpability.

A market search and feasibility study was conducted on strain gauging of retardant aircraft, in-line viscometers, and specific gravity meters and flow meters for liquid concentrate (L.C.)

retardant bases. Two flow meters, one specific gravity meter, and an electrically driven pump were tested at the Medford Airtanker Base, Ore.

In addition, three friction-reducing chemicals and induction systems have been tested, and an *Equip Tips* is being published on the two successful ones.

The Hale 20FD and the Mark 26 pumps have been successfully tested, along with numerous other accessories including hose, couplings, wye valves, and backpack pumper units.

A Chemonics L.C. prototype blender unit has been tested and installed on a Model 51 tanker for field evaluation. Also, a dry powder blender system is currently under test and will be placed in field service this fire season. A prototype portable weather shelter and plastic sheaths for pulaskis will also be placed in the field. If the plastic sheaths prove successful, the result will be over \$2.00 saving per sheath. Sheaths for other tools will be worked on next year.

The Helicopter Accessory Standard for medium and light helicopters was published in time for GSA to stock several of the high-use items, such as cargo nets, swivels, and lead lines.

The air crew helmet evaluation has been completed, and an *Equip Tips* is being published on the SPH4 helmet.

Over 6,000 copies of a new edition of the "Spark Arrester Guide" have been distributed in the field, and demand is increasing.

HELICOPTER NIGHT OPERATIONS

For the last two years, the Forest Service has been engaged in a Research and Development program to expand helicopter firefighting operations into night hours by using current night-vision technology. A Forest Service grant to the County of Los Angeles to provide experienced operational flight crews for experimental development activities with the San Dimas Center has resulted in routine helicopter night operations by the County Fire Department when emergencies have required this service. The Los Padres National Forest, Calif., is the home base for the first helicopter contractor trained and equipped for night operations on forest fires. This helicopter and crew are currently available for South Zone dispatching in the California Region. Not only were several fires fought during night hours, with delivery of suppressants for direct support of ground crews, but many search and rescue operations were also successfully conducted, which resulted in the rapid transport of the injured from mountains and remote highways to hospital facilities during the hours of darkness.

The low-light-level device, known as "Night Vision Goggles" or "NVG," has become popular for flight use. Night Vision Goggles have been used most successfully on fires when viewing hot spots or coals in the "near IR" region of the spectrum. In addition, NVG are being used successfully for other ground purposes, such as deterring nocturnal Christmas tree poachers, and for experimental evaluations as laser range pole viewers.

The new lightweight (73 lb) Forward Looking Infrared (FLIR) thermal imaging system was delivered and adapted to quick mounting on a Bell 205 helicopter at the end of 1975. It

provides a "real-time" TV display that operates in the 8-14 micron range of the IR spectrum. The equipment includes a video tape recorder that provides a record of the scene that is visible to the eye. The IR will pass through smoke and operates day or night, providing a new tool for the Land Manager to record environmental data. Since the imagery is temperature-related, there will, no doubt, be future engineering uses. Currently, a similar FLIR system is being used for recording temperature gradients in the Alaskan pipeline.

PERSONNEL CHANGES

Since the beginning of the year, SDEDC Director Boone Richardson has had a number of changes and additions to his staff. Mike Lambert was promoted to the Washington Office in the position of Staff Engineer vacated by Don Sirois. Claude Airall, Mechanical Engineer, was promoted to Mike Lambert's vacated seat. Phillip Fischer, Supervisory Civil Engineer on the Ochoco National Forest, Region 6, accepted the position previously held by Claude Airall. Dave Jones, Washington Office Materials Engineer, transferred to San Dimas as the Staff Assistant for Engineering Materials Investigations and Studies. Luigi DeBernardo took over a new position as the Staff Assistant for Fire Prevention and Related Activities. In this position, he provides the technical expertise and engineering leadership to the design and development of fire prevention equipment and equipment systems. Jerry Edwards, Region 8 Equipment Development Engineer, transferred to San Dimas to assume Luigi DeBernardo's position as Assistant Director for Development and Testing.

CONSULTATION & STANDARDS

Charles R. Weller
Assistant Director

NATIONAL SIGN PROCUREMENT COORDINATOR

The National Sign Procurement Coordinator position, which is located in Atlanta, Ga., is in the process of being filled. The vacancy announcement, issued Service-wide, was closed July 8th.

It is hoped that by establishing this position the cost and delay in the procurement of signs from Federal Prison Industries (FPI) will be reduced. The benefit will undoubtedly be greatest for the Regions located closest to Atlanta. If the Atlanta position works well, a similar position to serve Western Regions may be considered for Lompoc, Calif., and any new sign shop operations that FPI may establish.

FPI is currently investigating the possibilities of establishing another sign shop somewhere west of Mississippi.

Manual directives and procedural guides for the procurement of signs from FPI are being developed. A rough draft of the material will be sent to the Regions soon for review and comment. We are hoping to have the position filled and operating by this fall.

CHANGE TO JUNE FIELD NOTES

Volume 8, Number 6

POLYESTER RESIN ANCHORAGE SYSTEM PRAIRIE PORTAGE DAM

Correct page 12, 4th paragraph, 3rd sentence to read:

Consequently, a jacking bridge bearing at a point four feet on each side of the bar was specified for use in the pullout test; this set-up would test the anchor as well as the rock for anchorage. The jack used for the pullout test was a hollow cylinder jack that fitted over the bar and rested on the jacking bridge.

**INVITATION TO READERS OF
*FIELD NOTES***

Every reader is a potential author of an article for *Field Notes*. If you have a news item or short article you would like to share with Service engineers, we invite you to send it for publication in *Field Notes*.

Material submitted to the Washington Office for publication should be reviewed by the respective Regional Office to see that the information is current, timely, technically accurate, informative, and of interest to engineers Service-wide (FSM 7113). The length of material submitted may vary from several short sentences to several typewritten pages; however, short articles or news items are preferred. All material submitted to the Washington Office should be typed double-spaced; all illustrations should be original drawings or glossy black and white photos.

Field Notes is distributed from the Washington Office directly to all Regional, Station, and Area Headquarters, Forests, and Forest Service retirees. If you are not currently on the mailing list ask your Office Manager or the Regional Information Coordinator to increase the number of copies sent to your office. Copies of back issues are also available from the Washington Office.

Each Region has an Information Coordinator to whom field personnel should submit both questions and material for publication. The Coordinators are:

R-1	Bill McCabe	R-4	Ted Wood	R-9	Norbert Smith
R-2	Allen Groven	R-5	Jim McCoy	R-10	Frank Muchmore
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Coordinators should direct questions concerning format, editing, publishing dates, and other problems to:

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