

AASHO Road Test

The AASHO Road Test, a \$27 million (1960 dollars) investment and the largest road experiment of its time, was conceived and sponsored by the American Association of State Highway Officials (AASHO) as a study of the performance of highway pavement structures of known thickness under moving loads of known magnitude and frequency (Highway Research Board, 1961). The test studied both portland cement concrete and asphaltic concrete pavements, as well as certain types of short-span bridges.

The information obtained from the AASHO Road Test was crucial in advancing knowledge of pavement [structural design](#), [pavement performance](#), [load equivalencies](#), [climate effects](#), and much more. The basic performance information resulted in the performance equations and nomographs used in the AASHO *Guide*. This section provides some background information on the AASHO Road Test. It should be helpful in understanding the experiment's strengths, weaknesses and limitations.

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Background

This section provides some of the basic background for the AASHO Road Test and is taken primarily from Highway Research Board's Special Report 61A, *The AASHO Road Test: History and Description of the Project* (1961).

Location: Ottawa, Illinois

The AASHO Road Test site (which eventually became part of I-80) at Ottawa, Illinois, was typical of northern climates (see Table 1).

Table 1: AASHO Road Test Weather

Average Mean Temperature (July)	24.5°C (76°F)
Average Mean Temperature (January)	-2.8°C (27°F)
Annual Average Rainfall	837 mm (34 inches)
Average Depth of Frost (for fine-grained soil)	711 mm (28 inches)

Time

- Construction: August 1956 - September 1958
- Test Traffic: October 1958 - November 1960
- Special Studies: Spring and early summer 1961

Test Facilities

- Six 2-lane test loops (see Figure 1)
- Loop 1 = not subject to traffic, used to test environmental effects
- Loops 2 through 6 = subject to traffic described in Figure 2

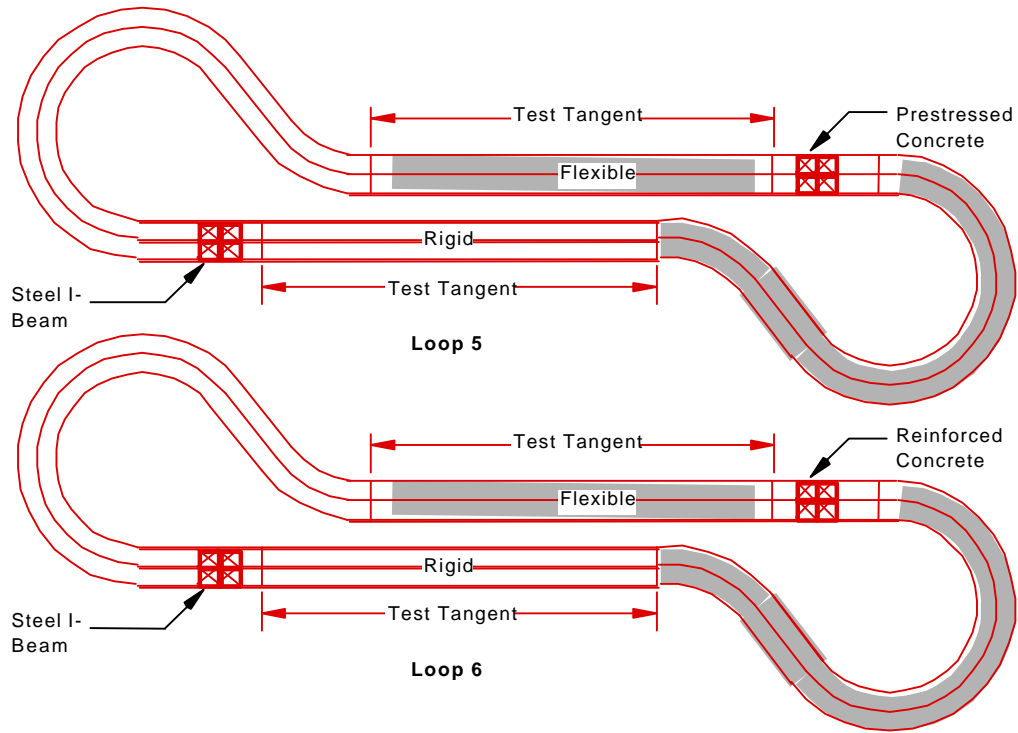


Figure 1: Loop 5 and 6 AASHO Road Test Layout (redrawn from Highway Research Board, 1961)

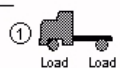
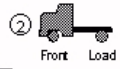
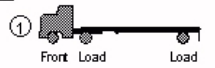







Loop	Lane	Weight in Kips			
		Front Axle	Load Axle	Gross Weight	
②	①		2	2	4
	②		2	6	8
③	①		4	12	28
	②		6	24	54
④	①		6	18	42
	②		9	32	73
⑤	①		6	22.4	50.8
	②		9	40	89
⑥	①		9	30	69
	②		12	48	108

Figure 2: Axle Weights and Distributions Used on Various Loops of the AASHO Road Test (redrawn from Highway Research Board, 1961)

Performance Measurements

The following measurements of performance were collected:

- [Roughness](#) and [visual distress](#)
- [Deflections](#), strains, etc.
- [Pavement Serviceability Index \(PSI\)](#)

Flexible Pavement Materials

(Information for this section taken from Highway Research Board, 1962a and Highway Research Board, 1962b)

The primary materials used in the flexible pavement sections will be briefly described below. This kind of information is helpful in comparing a particular project's set of materials to those used at the Road Test.

HMA

The HMA mixes used at the Road Test used:

- Crushed limestone coarse aggregate
- Natural siliceous coarse sand
- Mineral filler which was limestone dust
- [Penetration grade](#) asphalt cement (85-100 pen)

The gradation requirements for the surface and binder courses are given in Table 2.

Table 2: AASHO Road Test HMA Gradation Requirements

Sieve	Surface Course Gradation Limits	Binder Course Gradation Limits
1 in.		100
3/4 in.	100	88-100
1/2 in.	86-100	55-86
3/8 in.	70-90	45-72
No. 4	45-70	31-50
No. 10	30-52	19-35
No. 20	22-40	12-26
No. 40	16-30	7-20
No. 80	9-19	4-12
No. 200	3-7	0-6

For the HMA surfaced test sections (in Loops 3-6), the surface course was 1.5 inches thick. The HMA mixes were designed by the [Marshall method](#) using 50 blows per face. The typical field asphalt contents were about 5.4 and 4.4 percent by weight of total mix for the surface and binder courses, respectively. The field [air voids](#) averaged 7.7 percent for the six test loops.

Base Course

The base course material was a crushed dolomitic limestone that conformed to the gradation range shown in Table 3.

Table 3: AASHO Road Test Base Course Gradation Requirements

Sieve	Specification Range Percent Passing	Actual Mean Percent Passing
1-1/2 in.	100	100
1 in.	80-100	90
3/4 in.	70-90	81
1/2 in.	60-80	68
No. 4	40-60	48
No. 10	28-46	35
No. 40	16-33	20
No. 100	7-20	13.5
No. 200	3-12	10

It is significant to note that 10 percent passed the 0.075 mm (No. 200 sieve). Thus, the base was likely a bit [frost susceptible](#). The [CBR](#) of the base material averaged 107.7 percent based on laboratory tests; however, the test results ranged from a low of 52 percent to a high of 160 percent (total of 11 tests). The minimum specified CBR was 75 percent. Typical in-place mean dry densities were about 2242 to 2275 kg/m³ (140 to 142 lb/ft³), with mean moisture contents ranging from 5.6 to 6.1 percent.

Subbase Course

The subbase material was a sand-gravel mixture which conformed to the following gradation range shown in Table 4.

Table 4: AASHO Road Test Subbase Course Gradation Requirements

Sieve	Specification Range Percent Passing	Actual Mean Percent Passing
1-1/2 in.	100	100
1 in.	95-100	100
3/4 in.	90-100	96
1/2 in.	80-100	90
No. 4	55-100	71
No. 10	40-80	52
No. 40	10-30	25
No. 200	5-9	6.5

The CBR was specified **not to exceed** 60 percent. Typical laboratory CBR values ranged from 28 to 51 percent. The mean percent passing the 0.075 mm (No. 200) sieve was 6.5 percent (a lesser percentage than the base course). Typical in-place mean dry densities ranged from 2227 to 2259 kg/m³ (139 to 141 lb/ft³), with moisture contents ranging from 6.1 to 6.8 percent.

Subgrade

One Road Test requirement was that all test pavements be built on a uniform embankment with the top 1 m (3 ft.) constructed of an [A-6](#) soil. Tests on this soil revealed:

$$\begin{aligned} LL &= 31\% \\ PI &= 16\% \\ P_{200} &= 82\% \\ \gamma_{dmax} &= 119 \text{ lb/ft}^3 \\ \text{Optimum Water Content} &= 13\% \end{aligned}$$

Field CBR and density tests on the completed embankment just prior to paving were (5.12):

$$\begin{aligned} \text{Average CBR} &= 2.9 \\ \text{CBR Range} &= 1.9 - 3.5 \\ \text{Average Saturation} &= 85\% \\ \text{Average Compaction} &= 98.5\% \\ \text{Average Water Content} &= 13.8\% \end{aligned}$$

Flexible Pavement Designs

(Information for this section taken from Highway Research Board, 1962a and Highway Research Board, 1962b)

The structural design portion of the AASHO Road Test flexible pavement experiment was designed as a full factorial experiment with the design factors being:

- surfacing thickness
- base thickness
- subbase thickness

To accomplish the many different factorial combinations, the test loops were divided up into small test sections. Overall, there were 288 different flexible pavement test sections in the main experiments (332 counting replications).

Each flexible pavement section in the main experiment was 30 m (100 ft.) long with all sections being separated by a transition pavement of at least 5 m (15 ft.) Table 5 summarizes the thicknesses for each loop.

Table 5: AASHO Road Test Structural Design Thickness Summary

Loop No.	AC Thickness (in.)	Base Thickness (in.)	Subbase Thickness (in.)
1	1.0	0.0	0.0
	3.0	6.0	8.0
	5.0	--	16.0
2	1.0	0.0	0.0
	2.0	3.0	4.0
	3.0	6.0	8.0
3	2.0	0.0	0.0
	3.0	3.0	4.0
	4.0	6.0	--
4	3.0	0.0	4.0
	4.0	3.0	8.0
	5.0	6.0	12.0
5	3.0	3.0	4.0
	4.0	6.0	8.0
	5.0	9.0	12.0
6	4.0	3.0	8.0
	5.0	6.0	12.0
	6.0	9.0	16.0

Flexible Pavement Performance

Of the various axle loads applied to each of the test loops, a total of 1,114,000 load applications were made (not [ESALs](#)). Of the 332 test sections, 264 sections (or 80 percent) had reached a [PSI](#) of 1.5 or less on or before the end of the load application period (from November 1958 to June 1960). Tables 6 and 7 are used to overview the actual performance for Loops 4 and 6 (Loop 4 had an 18,000 lb single axle as one of its standard loads and Loop 6 had the heaviest axle loads used at the Road Test). Data from these two loops are shown because they are likely of the greatest contemporary interest. Table 6 shows that increasing AC thickness (from 3.0 to 5.0 in.) results in increased performance (number of loads until failure); however, not at as significant a rate as one might expect. Similar results are observed for Loop 6.

Each section, if it reached a PSI of 1.5 prior to completion of all load applications (recall the total was 1,114,000 axle repetitions) was overlaid with new AC so that the trucks applying the loads could safely continue. For Loop 4, all of these overlays were applied during the months of March, April, and May. For Loop 6, 75 percent of the overlays were applied during March, April, and May. This suggests that [freeze-thaw effects](#) strongly influenced flexible pavement performance at the Road Test.

The [depth of freeze](#) varied a bit from year-to-year but averaged about 28 in. for the flexible sections and generally reached 30 in. Such performance might provide additional insight into the required depth of pavement to resist freeze-thaw effects.

Table 6: AASHO Road Test Loop 4 Results^{2,3}—Flexible Test Sections (after Highway Research Board, 1962b)

AC Thickness (in.)	Axle	Base and Subbase Thicknesses (in.)								
		0.0			3.0			6.0		
		4.0	8.0	12.0	4.0	8.0	12.0	4.0	8.0	12.0
3.0	18,000 lb single	2,000	72,000	98,000	74,000	82,000	583,000	80,000	92,000	(1.6)
	32,000 lb tandem	12,000	74,000	110,000	76,000	86,000	601,000	80,000	570,000	618,000
4.0	18,000 lb single	78,000	107,000	426,000	87,000	106,000	1,110,000	90,000	(1.9)	(1.9)
	32,000 lb tandem	83,000	102,000	576,000	93,000	144,000	796,000	120,000	(2.0)	(3.1)
5.0	18,000 lb single	88,000	119,000	676,000	125,000	589,000	592,000	626,000	(3.6)	(3.3)
	32,000 lb tandem	102,000	126,000	850,000	151,000	752,000	(2.2)	678,000	(2.7)	(2.7)

Notes:

1. Replicate sections averaged
2. Values in parentheses are PSI at end of load applications
3. Values not in parentheses are the numbers of load applications to reach a PSI = 1.5

Table 7: AASHO Road Test Loop 6 Results—Flexible Test Sections (after Highway Research Board, 1962b)

AC Thickness (in.)	Axle	Base and Subbase Thicknesses (in.)								
		3.0			6.0			9.0		
		8.0	12.0	16.0	8.0	12.0	16.0	8.0	12.0	16.0
4.0	30,000 lb single	72,000	373,000	112,000	82,000	83,000	552,000	82,000	353,000	(2.0)
	48,000 lb tandem	80,000	573,000	362,000	373,000	100,000	621,000	82,000	353,000	(2.0)
5.0	30,000 lb single	78,000	101,000	573,000	100,000	522,000	(1.8)	595,000	719,000	(3.3)
	48,000 lb tandem	103,000	419,000	652,000	105,000	606,000	809,000	624,000	722,000	(3.5)
6.0	30,000 lb single	141,000	113,000	627,000	106,000	(1.6)	(3.2)	624,000	(2.4)	(2.7)
	48,000 lb tandem	579,000	485,000	(2.4)	250,000	(3.0)	(3.9)	(2.2)	(2.6)	(3.6)

Notes:

1. Replicate sections averaged
2. Values in parentheses are PSI at end of load applications
3. Values not in parentheses are the numbers of load applications to reach a PSI = 1.5

Tables 8 and 9 summarize information from Tables 6 and 7.

Table 8: Loop 4 (18,000 lb Single Axle) Summary

AC Thickness (in.)	Averaged Total Depth of Pavement (in.) and Percent of Frost Depth ^{1,2}		
	"Poor" Performance <500,000 reps	"Average" Performance >500,000 reps	"Better" Performance >1,114,000 reps
3.0	12.4 (41%)	19.5 (65%)	21.0 (70%)
4.0	12.7 (42%)	19.7 (65%)	20.0 (67%)
5.0	11.3 (38%)	18.3 (61%)	21.0 (70%)

Notes:

1. Frost depth = 30 in.
2. Load repetitions to a PSI of 1.5 (<500,000; >500,000) and load repetitions to greater than 1,114,000 (PSI > 1.5).

Table 9: Loop 6 (30,000 lb Single Axle) Summary

HMA Thickness (inches)	Averaged Total Depth of Pavement (in.) and Percent of Frost Depth ^{1,2}		
	"Poor" Performance <500,000 reps	"Average" Performance >500,000 reps	"Better" Performance >1,114,000 reps
4.0	20.1 (67%)	27.5 (92%)	29.0 (97%)
5.0	18.3 (61%)	25.3 (84%)	28.5 (95%)
6.0	19.3 (64%)	26.3 (88%)	27.5 (92%)

Notes:

1. Frost depth = 30 in.
2. Load repetitions to a PSI of 1.5 (<500,000; >500,000) and load repetitions to greater than 1,114,000 (PSI > 1.5).

Based on the three categories of load repetitions (less than 500,000; more than 500,000; more than 1,114,000) from Tables 8 and 9, the total thickness of the base and subbase layers had a significant influence on the load repetitions. Given such information and the fact that most of the flexible sections which reached a PSI of 1.5 before completion of the Road Test traffic were overlaid immediately following the spring thaw (that is, the months of March, April, and May), then two preliminary observations are made:

1. For low ESAL pavements (say 500,000 ESALs or less as illustrated by Loop 4), the total depth of the pavement should be about 65 percent of the expected depth of frost.
2. For pavements subjected to much higher axle loads (say ESALs of about 5,000,000 or more) as illustrated by Loop 6 (recall the [Load Equivalency Factor](#) for a 30,000 lb single axle is about 8.0), the total depth of the pavement should be about 90 to 100 percent of the expected depth of frost.

It is as yet uncertain as to whether such percentages as noted above apply to frost depths greater than say 30 in., since the evidence from the Road Test applies to a unique set of materials (base, subbase, and subgrade) and moisture conditions.

Equivalent Single Axle Loads

The design concept of the equivalent single axle load (ESAL) emerged from the AASHO road test and its volumes of data. Both the flexible and rigid ESAL equations and their corresponding calculated load equivalency factors (LEFs) are still used today in the 1993 AASHTO *Guide*. Although these equations and LEFs are reasonably accurate, a study conducted by Irick et al. (1991) for the Trucking Research Institute (TRI) reanalyzed the AASHO Road Test data with regard to estimation of LEFs. In general, the TRI study showed that LEFs for both flexible and rigid pavements should be larger for lighter loaded axles and smaller for heavier loaded axles as compared to AASHTO LEFs. Further, the LEFs for rigid pavements would be reduced for single axle loads greater than 80 kN (18,000 lb.) and tandem axle loads greater than 151 kN (34,000 lb.) as compared to AASHTO. The following LEFs from the TRI study and AASHTO illustrate these points:

Table 10: TRI vs. AASHTO LEFs for Flexible and Rigid Pavements

		LEFs for $p_t = 2.5$			
		Single Axle = 12,000 lb		Single Axle = 30,000 lb	
Pavement Type	SN	TRI	AASHTO	TRI	AASHTO
Flexible	3.06	0.25	0.21	5.6	7.8
	4.36	0.24	0.21	6.2	6.9
		Tandem Axle = 24,000 lb		Tandem Axle = 48,000 lb	
Pavement Type	SN or D	TRI	AASHTO	TRI	AASHTO
Flexible	3.06	0.34	0.32	3.5	4.2
	4.36	0.32	0.28	3.7	4.1
Rigid	8.0-in.	0.65	0.45	3.8	7.3
	9.5-in.	0.66	0.44	3.7	7.9

Thus, in general, for the heavier axle loads, the TRI study showed that single axle flexible LEFs would be somewhat higher than rigid LEFs. Tandem axle flexible and rigid LEFs would be about the same.

Rigid Pavement Materials

(Information for this section taken from Highway Research Board, 1962a and Highway Research Board, 1962b)

The primary materials used in the rigid pavement sections will be briefly described below. This kind of information is helpful in comparing a particular project's set of materials to those used at the Road Test.

Portland Cement Concrete

- Cement type = Type I
- Design cement content = 564 lb/yd³
- Design maximum water content = 5.3 gal/bag of cement (equates to a water-cement ratio of 0.47)
- Design strength (14 day cure):
 - Minimum compressive strength = 3500 psi
 - Minimum modulus of rupture (flexural strength) = 550 psi (using a [third-point loading test](#))

- Design slump range: 1.5 to 2.5 in.
- Maximum aggregate sizes: 1.5 and 2.5 in.
- Linear coefficient of thermal expansion = 4.6 to 5.1 x 10⁻⁶ per °F

Table 11: Fresh PCC Parameters

Parameter	Maximum Aggregate Size	
	1.5 inch	2.5 inch
Mean slump (inches)	2.7	2.5
Mean air content (%)	4.2	3.7
Mean cement content	571	572

Table 12: Strength Properties

Age	Maximum Aggregate Size			
	1.5 inch		2.5 inch	
	Compressive Strength (psi)	Flexural Strength (psi)	Compressive Strength (psi)	Flexural Strength (psi)
3 days	2860	550	2670	510
7 days	3780	630	3560	620
14 days	4004	668	3966	636
21 days	4250	710	4130	660
1 year	5990	880	5580	790
2 years	6155	873	5818	787

Subbase Course

The subbase course used beneath the PCC slabs was the same material as used for the [subbase course in the flexible pavement sections](#).

Subgrade

The subgrade was the same as that under the flexible sections.

Rigid Pavement Designs

Overall, there were 260 rigid pavement test sections in the main experiment (312 counting replicates). Reinforced sections were 240 ft long with sawed, doweled transverse contraction joints spaced 40 ft apart. Non-reinforced sections were 120 ft long with sawed, doweled transverse contraction joints spaced 15 ft apart (no expansion joints). Dowel bar sizes varied with slab thickness. Reinforcement was welded steel fabric placed about 2 in. from the slab surface. Table 13 shows the various structural design parameters for each rigid pavement section.

Table 13: Rigid Pavement Structural Design Parameters

Loop No.	PCC Slab Thickness (in.)	Subbase Thickness (in.)	Transverse Dowel Bars (Diameter x Length)
1	2.5	0, 6.0	3/8" x 12"
	5.0	0, 6.0	5/8" x 12"
	9.5	0, 6.0	1 1/4" x 18"
	12.5	0, 6.0	1 5/8" x 18"
2	2.5	0, 3.0, 6.0	3/8" x 12"
	3.5	0, 3.0, 6.0	1/2" x 12"
	5.0	0, 3.0, 6.0	5/8" x 12"
3	3.5	3.0, 6.0, 9.0	1/2" x 12"
	5.0	3.0, 6.0, 9.0	5/8" x 12"
	6.5	3.0, 6.0, 9.0	7/8" x 18"
	8.0	3.0, 6.0, 9.0	1" x 18"
4	5.0	3.0, 6.0, 9.0	5/8" x 12"
	6.5	3.0, 6.0, 9.0	7/8" x 18"
	8.0	3.0, 6.0, 9.0	1" x 18"
	9.5	3.0, 6.0, 9.0	1 1/4" x 18"
5	6.5	3.0, 6.0, 9.0	7/8" x 18"
	8.0	3.0, 6.0, 9.0	1" x 18"
	9.5	3.0, 6.0, 9.0	1 1/4" x 18"
	11.0	3.0, 6.0, 9.0	1 3/8" x 18"
6	8.0	3.0, 6.0, 9.0	1" x 18"
	9.5	3.0, 6.0, 9.0	1 1/4" x 18"
	11.0	3.0, 6.0, 9.0	1 3/8" x 18"
	12.5	3.0, 6.0, 9.0	1 5/8" x 18"

Rigid Pavement Performance

Of the various axle loads applied to each of the test loops, a total of 1,114,000 load applications were made (not ESALs). Of the 312 rigid test sections, only 67 sections (or 21 percent) had reached a PSI of 1.5 or less at the end of the load application period (from November 1958 to June 1960). Tables 14 and 15 are used to overview the actual performance for Loops 4 and 6 (Loop 4 had an 18,000 lb single axle as one of its standard loads and Loop 6 had the heaviest axle loads used at the Road Test). Data from these two loops are shown because they are likely of the greatest contemporary interest. Table 14 reveals that the then standard axles caused failure in up to the 6.5 in. thick PCC slabs (8.0 in. and thicker slabs did not fail). For the heavier axles used in Loop 6, slabs up to 9.5 in. failed but 11 inch and thicker slabs did not fail. Further, subbase thickness did not seem to matter much.

Table 14: AASHO Road Test Loop 4 Results^{2,3}—Rigid Test Sections (after Highway Research Board, 1962b)

PCC slab Thickness (in.)	Axle	Subbase Thicknesses (in.)					
		3.0		6.0		9.0	
		JPCP	JRCP	JPCP	JRCP	JPCP	JRCP
5.0	18,000 lb single	716,000	415,000	353,000	325,000	291,000	592,000
	32,000 lb tandem	343,000	304,000	328,000	175,000	298,000	408,000
6.5	18,000 lb single	(3.8)	(3.6)	(4.3)	(3.4)	(3.0)	(1.8)
	32,000 lb tandem	687,000	793,000	1,000,000	796,000	722,000	1,036,000
8.0	18,000 lb single	(4.5)	(3.9)	(4.4)	(3.9)	(4.3)	(4.3)
	32,000 lb tandem	(4.2)	(4.0)	(4.3)	(3.8)	(4.1)	(4.2)

Notes:

1. Replicate sections not shown
2. Values in parentheses are PSI at end of load applications
3. Values not in parentheses are the numbers of load applications to reach a PSI = 1.5.

Table 15: AASHO Road Test Loop 6 Results^{2,3}—Rigid Test Sections (after Highway Research Board, 1962b)

PCC Slab Thickness (in.)	Axle	Subbase Thicknesses (in.)					
		3.0		6.0		9.0	
		JPCP	JRCP	JPCP	JRCP	JPCP	JRCP
8.0	30,000 lb single	878,000	782,000	(3.9)	974,000	(3.4)	768,000
	48,000 lb tandem	618,000	(1.8)	(4.1)	415,000	1,114,000	624,000
9.5	30,000 lb single	(3.6)	(1.6)	(4.3)	(4.0)	(4.2)	(2.2)
	48,000 lb tandem	(3.1)	(4.1)	(4.3)	(4.0)	(4.3)	912,000
11.0	30,000 lb single	(4.4)	(4.4)	(4.2)	(4.3)	(4.3)	(4.2)
	48,000 lb tandem	(4.3)	(4.4)	(4.3)	(4.2)	(4.3)	(4.1)
12.5	30,000 lb single	(4.2)	(4.4)	(4.0)	(4.2)	(4.2)	(4.5)
	48,000 lb tandem	(4.3)	(4.3)	(4.2)	(4.4)	(4.4)	(4.2)

Notes:

1. Replicate sections not shown
2. Values in parentheses are PSI at end of load applications
3. Values not in parentheses are the numbers of load applications to reach a PSI = 1.5.