

# Summary of Pavement Performance Tests Using the Accelerated Loading Facility, 1986–1990

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FHWA has been conducting pavement performance tests using the Accelerated Loading Facility (ALF) for more than 5 years. Tests have been performed at the FHWA Pavement Testing Facility (PTF) during two research projects and at in-service sites in Montana and Wyoming. The first phase of pavement research at the PTF established operations and data collection procedures and assessed the rationality of performance data collected with the ALF. Data obtained during the PTF Phase 1 research showed that pavement performance under the ALF loading followed the general trends observed through monitoring of various test roads and in-service pavements. The in-service testing program demonstrated the mobility of the ALF, and experience with site preparation, traffic control, and site restoration was obtained. The rutting performance of an asphalt mixture specifically designed to resist rutting was evaluated in a Montana field test, which showed that the use of the antirutting mixture may delay the development of rutting, but that plastic flow, which has been identified as the major cause of severe rutting, was not eliminated. The PTF Phase 2 research, which compared the damage potential of conventional dual and wide-based single tires, featured the comparative testing capabilities of the ALF. In this experiment, the control was the dual-tire loading and the treatment was the wide-based single-tire loading. Findings to date show the wide-based single tire to be significantly more damaging to flexible pavements than conventional dual tires.

In 1984 FHWA began an accelerated pavement testing research program. The initial phase of this program was directed at the acquisition of a mobile, linear-tracking, accelerated loading device. Two mobile devices were operational at that time: the Australian Accelerated Loading Facility (ALF), and the South African Heavy Vehicle Simulator. In September 1984, FHWA entered into an agreement with the Department of Main Roads, New South Wales, Australia, to provide plans, specifications, and technical assistance for the construction of an ALF in the United States. Construction of the U.S. ALF began in July 1985, and the completed machine was delivered to the Turner-Fairbank Highway Research Center (TFHRC) in August 1986.

The initial phase of the FHWA accelerated pavement testing program also provided for the establishment of a permanent pavement testing laboratory, the Pavement Testing Facility (PTF), at TFHRC. The PTF was constructed in summer 1986 as an outdoor facility with eight test sections. It was subsequently expanded to 12 test sections during the first pavement reconstruction in 1989.

The ALF has been in nearly continuous operation since its delivery to FHWA in 1986. From August 1986 through March 1989, the first phase of pavement research was conducted at the PTF. On completion of the Phase 1 research, a field testing program was conducted from April through December 1989. The field testing was performed in conjunction with the Western Association of State Highway and Transportation Officials (WASHTO), the states of Montana and Wyoming, and the U.S. Army Corps of Engineers. Test sections on I-90 near Columbus, Montana, and Sheridan, Wyoming, were tested, and a brief demonstration test was conducted for the Corps at the Waterways Experiment Station in Vicksburg, Mississippi. The ALF then returned to the TFHRC in January 1990 and the second phase of pavement research at the PTF began. For the Phase 2 research, the PTF was expanded to 12 test sections, and the ALF was modified to permit rapid movement between two adjacent test sections. This capability reduces environmental variations for comparative tests and is expected to play a major role in future PTF research programs.

## OBJECTIVE AND SCOPE

The accelerated pavement performance tests conducted with the ALF between August 1986 and December 1990 are summarized. During this period, tests were conducted on the 12 flexible pavements given in Table 1. For each of these tests, histories of rutting, cracking, roughness, and present serviceability index (PSI) were obtained as a function of the number of load applications. Environmental data including air and pavement temperatures and precipitation were collected during the tests to aid in the interpretation of the performance data. On completion of each test, postfailure analyses were conducted to document the condition of the pavement layers at the time of failure.

## ALF PAVEMENT TESTING MACHINE

The ALF pavement testing machine is a 100-ft-long structural frame containing a moving wheel assembly that travels 12 mph on rails attached to the frame and is in contact with the pavement for 38 ft. At the ends of the frame, the rails curve upward to permit gravity to accelerate, decelerate, and change direction of the wheel assembly. Loads are applied to the

TABLE 1 Summary of Pavement Tests with the ALF 1986-1990

No.	Location	Dates	Surface		Base		Loading		
			Type	Th. (in)	Type	Th. (in)	Load (lbs)	Tire Type	Pres. (psi)
1	PTF Phase 1, Lane 2, Section 3	01/08/87 - 06/04/87	AC <sup>a</sup>	7.0	CAB <sup>b</sup>	12.0	19,000	Dual	100
2	PTF Phase 1, Lane 2, Section 2	06/18/87 - 11/30/87	AC	7.0	CAB	12.0	19,000	Dual	140
3	PTF Phase 1, Lane 1, Section 2	12/14/87 - 02/18/88	AC	5.0	CAB	5.0	11,600	Dual	100
4	PTF Phase 1, Lane 1, Section 4	03/01/88 - 03/08/88	AC	5.0	CAB	5.0	16,400	Dual	100
5	PTF Phase 1, Lane 1, Section 1	03/24/88 - 04/04/88	AC	5.0	CAB	5.0	14,100	Dual	100
6	PTF Phase 1, Lane 2, Section 1	04/29/88 - 12/03/88	AC	7.0	CAB	12.0	16,400	Dual	100
7	PTF Phase 1, Lane 2, Section 4	01/09/89 - 02/23/89	AC	7.0	CAB	12.0	22,500	Dual	100
8	I-90, Columbus, MT	05/10/89 - 07/28/89	AC	9.8	CAB	20.4	19,000	Dual	100
9	I-90, Sheridan, WY	08/07/89 - 10/20/89	AC	4.8	CTB <sup>c</sup>	13.0	19,000	Dual	100
10	PTF Phase 2, Lane 1, Section 4	01/10/90 - 04/30/90	AC	5.0	CAB	12.0	14,100	Dual	100
11	PTF Phase 2, Lane 2, Section 1	09/20/90 - 01/18/91	AC	3.0	CAB	12.0	12,200	Dual	102
12	PTF Phase 2, Lane 3, Section 1	09/20/90 - 01/18/91	AC	3.0	CAB	12.0	12,200	Sgl	102

<sup>a</sup> Asphalt Concrete  
<sup>b</sup> Crushed Aggregate Base  
<sup>c</sup> Cement Treated Base

pavement in one direction, and the loads can be distributed laterally to simulate traffic wander.

Figure 1 shows the trolley assembly used to apply loads to the test pavement. The wheel assembly can be detached from the trolley through a bolted connection at the elevation of the load cells (Figure 1a). The ALF has single- and dual-tire wheel assemblies that model one-half of a single axle. The loads applied to the pavement can be varied from 9,000 to 22,500 lb by adding or subtracting ballast weights. Thus, dual- or single-tire single axles with loads ranging from 18,000 to 45,000 lb can be simulated.

For all of the tests described in this paper, traffic wander was simulated using a normal distribution of lateral wheel positions with a standard deviation of 5.25 in. The normal

distribution was truncated at 14.75 in., the maximum permissible lateral movement for the ALF. Figure 1b shows the geometry of the dual- and single-wheel assemblies used to apply the test loads. The centerline of the trolley moved through the lateral distribution, resulting in wheelpaths of 53 and 42 in. for the dual and single tires, respectively.

PAVEMENT PERFORMANCE TESTING

Data Collection

The objective of the pavement performance testing was to quantify the accumulation of structural and functional dis-

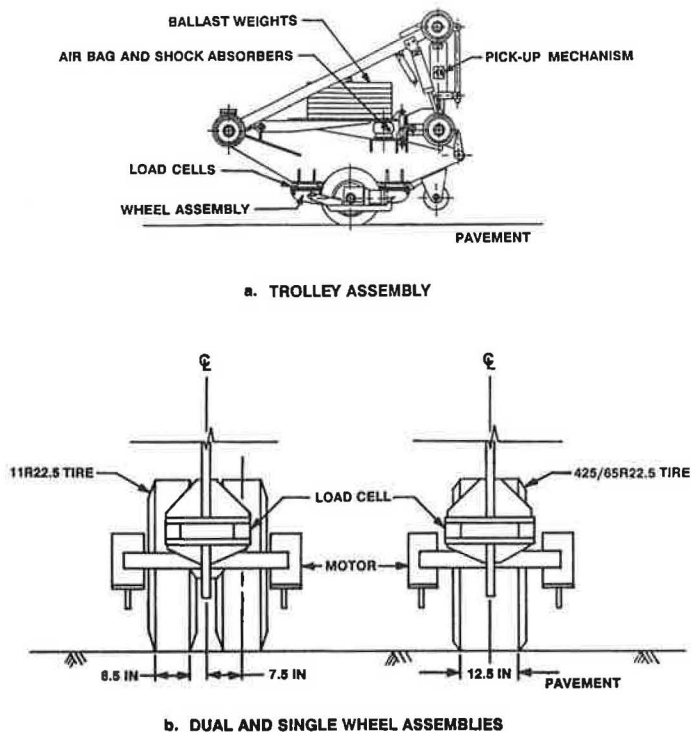


FIGURE 1 ALF loading.

tresses in the pavement test sections. Cracking and rutting data were obtained periodically during each of the accelerated load tests. The American Association of State Highway and Transportation Officials (AASHTO) serviceability concept was used to quantify the functional distress in terms of PSI. To supplement the performance data, postfailure investigations and materials testing were conducted on completion of the accelerated load testing. Since environmental control was not provided for any of the tests described in this paper, environmental conditions were closely monitored during each test to aid in the interpretation of the test data. Data collection equipment and procedures have been described in detail in previous reports (1,2).

### PTF Phase 1 Research Program

#### Objectives

The first phase of pavement research was conducted at the PTF from August 1986 through February 1989. The objectives of the Phase 1 research program were

1. To establish operating and data collection procedures for the PTF,
2. To assess the rationality of pavement response and performance data obtained with the ALF, and
3. To study pavement response and performance for a range of loads and tire pressures, with particular emphasis on the influence of tire pressure.

To accomplish these objectives, two types of tests, pavement response and accelerated loading, were conducted with the ALF. The response testing used the ALF's variable load capabilities and instrumentation installed in the test pavements. Response testing formed a major part of the tire pressure study conducted during the first phase of research. Details of the response testing and the tire pressure research have been presented elsewhere (3). The second type of test, accelerated loading, was used to collect pavement performance data as a function of the number of load repetitions. During accelerated loading, the ALF was controlled by a computer and operated 24 hr a day, 7 days a week. At typical productivity rates, approximately 5,500 load repetitions were applied to the test pavements daily.

#### Test Sections and Material Properties

For the first phase of research, the test sections at the PTF were constructed in two parallel lanes designated Lanes 1 and 2. Each lane was divided into four sections for a total of eight pavement test sections. The design cross sections consisted of a 2.0-in. asphalt concrete surface course and a 3.0-in. asphalt concrete binder course over a 5.0-in. crushed aggregate base for Lane 1, and a 2.0-in. surface course and 5.0-in. binder course over a 12.0-in. crushed aggregate base for Lane 2. Table 2 summarizes laboratory-determined material properties for each pavement layer.

TABLE 2 PTF Material Properties, Phase 1

Subgrade and Aggregate Base		
Property	Subgrade	Aggregate Base
Classification	A-4(0)	A-1-a
CBR	7 <sup>a</sup>	100 <sup>b</sup>
Average In-Situ Density	108 pcf 96% AASHTO T-99	143.8 pcf 94% AASHTO T-180
Average In-Situ Moisture		
As Constructed	10.0%	3.2%
Post Failure	17.0%	5.5%
Resilient Modulus <sup>c</sup>		
Reference 1		
$\sigma_d = 2$ psi	3400 ( $\theta$ ) <sup>0.52</sup>	5800 ( $\theta$ ) <sup>0.80</sup>
$\sigma_d = 5$ & 8 psi	1700 ( $\theta$ ) <sup>0.52</sup>	13300 ( $\theta$ ) <sup>0.80</sup>
Reference 4	3400 ( $\theta$ ) <sup>0.52</sup>	8830 ( $\theta$ ) <sup>0.23</sup>
Asphalt Concrete		
Property	Binder	Wearing
Asphalt Cement	AC-20	AC-20
Resilient Modulus, ksi <sup>d</sup>		
41 °F	2224	1855
77 °F	400	339
104 °F	73	67
Average Air Voids	3.41%	4.74%
Average Asphalt Content	4.70%	5.60%

<sup>a</sup> Laboratory Soaked per ASTM D1883

<sup>b</sup> Estimated from Dynamic Cone Penetrometer data

<sup>c</sup> Models yield  $M_r$  is psi for stresses in psi

$\sigma_d$  = deviatoric stress

$\theta$  = bulk stress

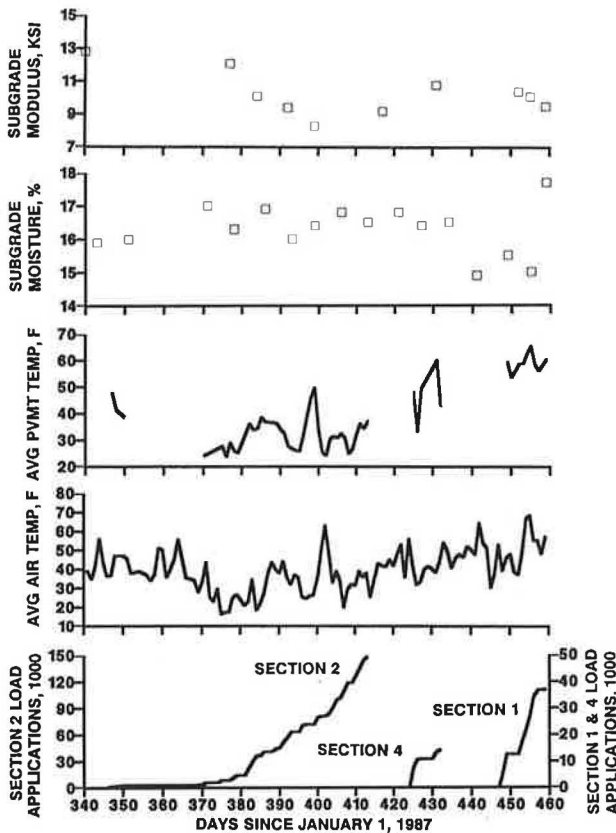
<sup>d</sup> From indirect tension tests

*Pavement Performance Results and Findings*

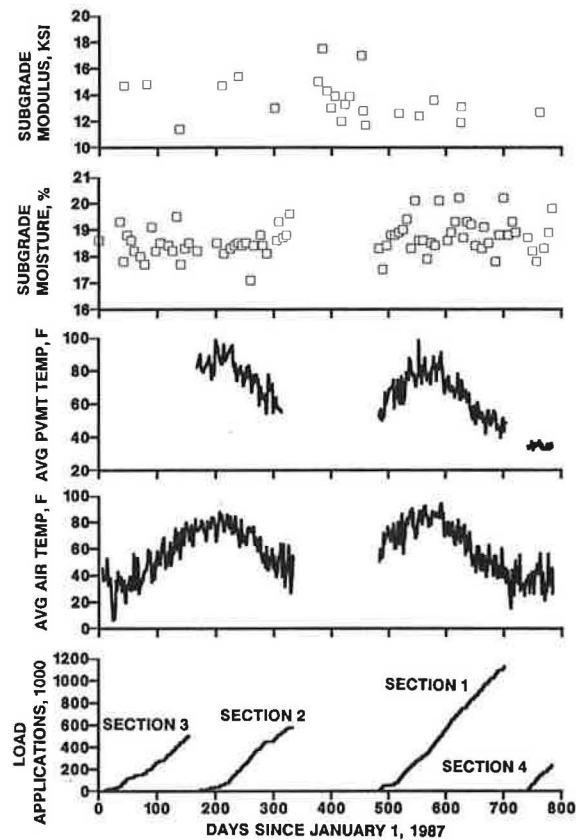
This section presents data from seven of the eight Phase 1 sections. The eighth section, Lane 1, Section 3, was used for initial shakedown testing of the ALF machine before the start of the pavement performance tests. The first phase of research included testing each lane with three load levels. For Lane 1, loads of 11,600, 14,100, and 16,400 lb were used, and loads of 16,400, 19,000 and 22,500 lb were used on Lane 2. All tests were conducted with dual 11R22.5 radial tires. The tire pressure was 100 psi for all sections except Lane 2, Section 2, which was tested at 140 psi as part of the tire pressure study.

Figures 2 and 3 summarize the loading history and the environmental and subgrade stiffness conditions for the Phase 1 tests. The subgrade moduli were estimated from falling weight deflectometer (FWD) data collected at untrafficked reference locations in Lanes 1 and 2 using the outer sensor deflection as described in AASHTO nondestructive testing (NDT) Method 2 (4). Because of the nonlinear behavior of the PTF subgrade soil, the estimated moduli may be somewhat higher than those occurring under the ALF loading. The nonlinear subgrade behavior also accounts for the difference in the estimated subgrade modulus between Lanes 1 and 2. The general trend in the modulus data shows a small decrease with time. This decrease was accompanied by a slight increase in subgrade moisture.

The results of the Phase 1 performance tests are summarized in Tables 3 and 4 for Lanes 1 and 2, respectively. Since



**FIGURE 2** Loading history and environmental conditions, PTF Phase 1, Lane 1.



**FIGURE 3** Loading history and environmental conditions, PTF Phase 1, Lane 2.

the ALF models half of a single axle, a pavement width of 6 ft was used in the computation of the percent cracking. The ALF wheelpath covers two-thirds of the 6-ft width; therefore, to obtain percent wheelpath cracking, the tabulated cracking data should be multiplied by 1.5.

Fatigue cracking was the predominant failure mode for the Phase 1 tests. Excessive rutting in the test sections did not develop until after the asphalt concrete was severely cracked. The test on Lane 2, Section 1, was cut short because of time constraints, but significant rutting and the onset of fatigue cracking were still observed in this test.

The pavement performance data obtained from the Phase 1 tests followed the general trends observed through monitoring of various test roads and in-service pavements. The effect of load on pavement damage was clearly evident. For tests conducted during warm weather, the rutting data showed rapid development of rutting, followed by a leveling-off period, followed by increased rutting after the initiation of fatigue cracks. As expected, the development of early rutting did not occur in the tests started during cold weather. The rapid development of fatigue cracking after crack initiation was clearly evident in all of the test sections. Fatigue cracks initiated transverse to the direction of travel of the ALF. After repeated load applications, longitudinal and additional transverse cracks appeared, resulting in the block or alligator cracking typical of fatigue failure. Finally, the loss of serviceability observed in the ALF tests was similar to that observed during the AASHTO Road Test.

TABLE 3 Performance Summary: PTF Phase 1 Research, Lane 1

Test Section	Date	No. of Passes	Slope Variance (10 <sup>-6</sup> )	Avg Rut Depth (in)	Avg Cracking (%) <sup>a</sup>	PSI Loss
Lane 1, Section 1						
	3/24/88	0	4.35	0.00	0	0.00
	3/28/88	12529	7.62	0.15	0	0.43
	3/30/88	21909	24.47	0.27	1	1.42
	3/31/88	26875	36.82	0.34	5	1.85
	4/ 1/88	34443	43.48	0.44	5	2.09
	4/ 4/88	37033	57.97	0.57	39	2.64
Lane 1, Section 2						
	12/14/87	0	1.78	0.00	0	0.00
	1/11/88	8481	1.78	0.03	0	0.00
	1/22/88	40875	2.03	0.05	0	0.07
	1/27/88	51782	3.43	0.10	4	0.46
	2/ 1/88	70685	12.02	0.15	21	1.45
	2/ 9/88	91013	23.20	0.16	21	1.97
	2/15/88	126485	41.00	0.21	29	2.48
	2/18/88	147696	79.28	0.28	36	3.08
Lane 1, Section 4						
	3/ 1/88	0	2.73	0.00	0	0.00
	3/ 3/88	10876	14.72	0.40	9	1.60
	3/ 8/88	13301	39.69	0.74	35	2.93
	3/ 9/88	14240	50.39	1.06	39	3.93

<sup>a</sup> Based on total pavement width. For wheelpath cracking multiply by 1.5.

Figures 4 and 5 present layer profiles obtained from the Phase 1 postfailure testing. For the Lane 2 tests, no rutting was observed in the subgrade; therefore, only the profiles of the pavement surface and the surface of the crushed aggregate base course are shown in Figure 5. For most of the Phase 1 tests, the majority of the rutting occurred in the crushed aggregate base layer. Rutting in the subgrade was only observed for tests using heavy loads on the thin pavement structure of Lane 1. The permanent deformation in the asphalt layer was small for all tests. Even Sections 1 and 2 of Lane 2, which were trafficked primarily during hot weather, exhibited less than 0.38 in. of rutting in the asphalt concrete.

### Montana and Wyoming Field Tests

#### Objectives

In 1989 a field testing program for the ALF was conducted in conjunction with WASHTO and the states of Montana and Wyoming. The objectives of this program were to document the benefits, costs, and difficulties associated with using the ALF to test in-service pavements and to evaluate the measures being taken in the WASHTO states to combat premature rutting in asphalt pavements (5).

#### Test Sections and Material Properties

The outer wheelpath of two pavement sections on I-90 was tested as part of this study. The first section, near Columbus, Montana, was a pavement rehabilitated in 1986 in accordance with the WASHTO antirutting guidelines (6). At the time of rehabilitation, the pavement cross section consisted of 6.0 in. of asphalt concrete over a 20.4-in. granular base. The asphalt

concrete, produced in accordance with the WASHTO anti-rutting guidelines, included an original 4.2-in. layer constructed in 1972 and a 1.8-in. overlay placed in 1978. The rehabilitation consisted of milling the 1978 overlay and placing a 1.8-in. inlay in the driving lane followed by a 3.0-in. overlay and 0.75-in. open graded friction course over both lanes.

The second test section, near Sheridan, Wyoming, was a cement-treated base section constructed in 1983. The pavement consisted of a 0.75-in. friction course and a 4.0-in. asphalt concrete surface course over a 13.0-in. cement-treated base. Table 5 summarizes laboratory-determined material properties for both the Montana and Wyoming test sections.

#### Pavement Performance Results and Findings

Figure 6 presents the loading and temperature histories for the Montana and Wyoming field tests. Both sections were tested with a 19,000-lb load on dual 11R22.5 radial tires inflated to 100 psi. Table 6 summarizes the performance data collected during the two field tests.

Both pavements had been trafficked but were in excellent condition before testing with the ALF. An estimated 750,000 18-kip equivalent single-axle loads (ESALs) had been applied to the Montana site since the 1986 rehabilitation. This traffic resulted in a 0.19-in. rut before the start of trafficking with the ALF. On completion of the test, the rut depth increased to 0.71 in. Observations during postfailure sampling and testing indicated that all the rutting occurred in the asphalt layer. Using the AASHTO 38,000-lb single-axle load equivalency of 11.2 (for a terminal serviceability of 3.0), the Montana section exceeded its design axle loading before the development of a 0.75-in. rut, the critical value established by the WASHTO committee for this study. Although the design life was exceeded, transverse surface profiles obtained during testing

TABLE 4 Performance Summary: PTF Phase 1 Research, Phase 2

Test Section	Date	No. of Passes	Slope Variance (10 <sup>-4</sup> )	Avg Rut Depth (in)	Avg Cracking (%) <sup>a</sup>	PSI Loss
Lane 2, Section 1						
	4/29/88	0	8.59	0.00	0	0.00
	6/ 8/88	137714	6.10	0.10	0	0.00
	6/17/88	190419	6.10	0.12	0	0.00
	6/23/88	223427	7.76	0.16	0	0.00
	7/ 7/88	288022	8.53	0.18	0	0.00
	7/14/88	316082	9.20	0.20	0	0.05
	7/21/88	339821	11.46	0.22	0	0.21
	7/27/88	377470	20.52	0.24	0	0.67
	8/ 3/88	425977	25.25	0.29	0	0.83
	8/17/88	519440	25.55	0.32	0	0.84
	8/24/88	566618	26.96	0.34	0	0.88
	8/31/88	623192	28.08	0.35	0	0.92
	9/21/88	749838	29.50	0.34	0	0.96
	10/12/88	849598	30.61	0.34	0	0.98
	10/26/88	934859	33.70	0.35	0	1.06
	11/ 3/88	976131	35.39	0.34	0	1.10
	11/18/88	1061098	42.54	0.34	2	1.25
	11/23/88	1091880	53.46	0.34	3	1.44
	12/ 3/88	1125385	61.55	0.34	4	1.55
Lane 2, Section 2						
	6/18/87	0	12.84	0.00	0	0.00
	7/21/87	37292	12.24	0.23	0	0.04
	8/18/87	130082	11.10	0.57	0	0.34
	10/15/87	450895	45.31	0.63	3	1.60
	11/30/87	578142	82.89	0.89	25	2.75
Lane 2, Section 3						
	1/ 5/87	0	10.03	0.00	0	0.00
	2/12/87	77475	6.96	0.05	0	0.00
	3/12/87	146896	10.84	0.08	0	0.07
	4/21/87	276949	21.56	0.30	0	0.75
	5/18/87	416812	41.54	0.76	2	2.03
	6/ 4/87	502662	-- <sup>b</sup>	--	9	--
Lane 2, Section 4						
	1/ 9/89	0	2.57	0.00	0	0.00
	1/18/89	44407	3.49	0.06	0	0.19
	1/25/89	81202	3.08	0.08	0	0.12
	2/ 1/89	131121	7.82	0.10	0	0.76
	2/ 8/89	164873	31.63	0.12	0	1.87
	2/15/89	186777	120.64	0.14	3	3.01
	2/27/89	233622	201.80	0.33	19	3.63

<sup>a</sup> Based on total pavement width. For wheelpath cracking multiply by 1.5.

<sup>b</sup> Data not collected

indicated the occurrence of plastic flow in the asphalt. Figure 7 shows the individual dual-tire tracks; plastic heave outside the wheelpath, accounting for almost one-half of the total rut depth, was clearly evident in the Montana pavement.

For the Wyoming site, an estimated 650,000 18-kip ESALs had been applied since construction in 1983. The test section exhibited typical cement-treated-base shrinkage cracks, which had been sealed as part of the normal maintenance program for this pavement. No rutting was evident at the start of the ALF test. The Wyoming test section was not significantly affected by the ALF traffic. Only a minor amount of rutting and a slight increase in roughness were detected.

### PTF Phase 2 Research Program

#### Objectives

While the ALF field tests were being conducted, the test pavements at the PTF were reconstructed for the Phase 2

research program. During this reconstruction, the PTF was expanded to include three parallel test lanes with a total of 12 pavement test sections.

Cold weather construction problems plagued the Lane 1 construction, rendering three of the four test sections untestable. The fourth section was tested in conjunction with the Organization for Economic Cooperation and Development (OECD) First OECD Road Common Experiment (FORCE) project (7). Funding and technical expertise for the FORCE project were obtained from 14 countries. The project included the conduct of a common accelerated load test at the circular pavement testing facility in Nantes, France, as well as several cross-checking accelerated tests at facilities in participating countries. Lane 1, Section 4, of the Phase 2 test sections served as the U.S. cross test.

The eight test sections in Lanes 2 and 3 were devoted to a comparative study of the damaging effect of dual and wide-based single tires. The study, which will be completed in the summer of 1992, included two complementary experiments: pavement response and pavement performance. The objec-

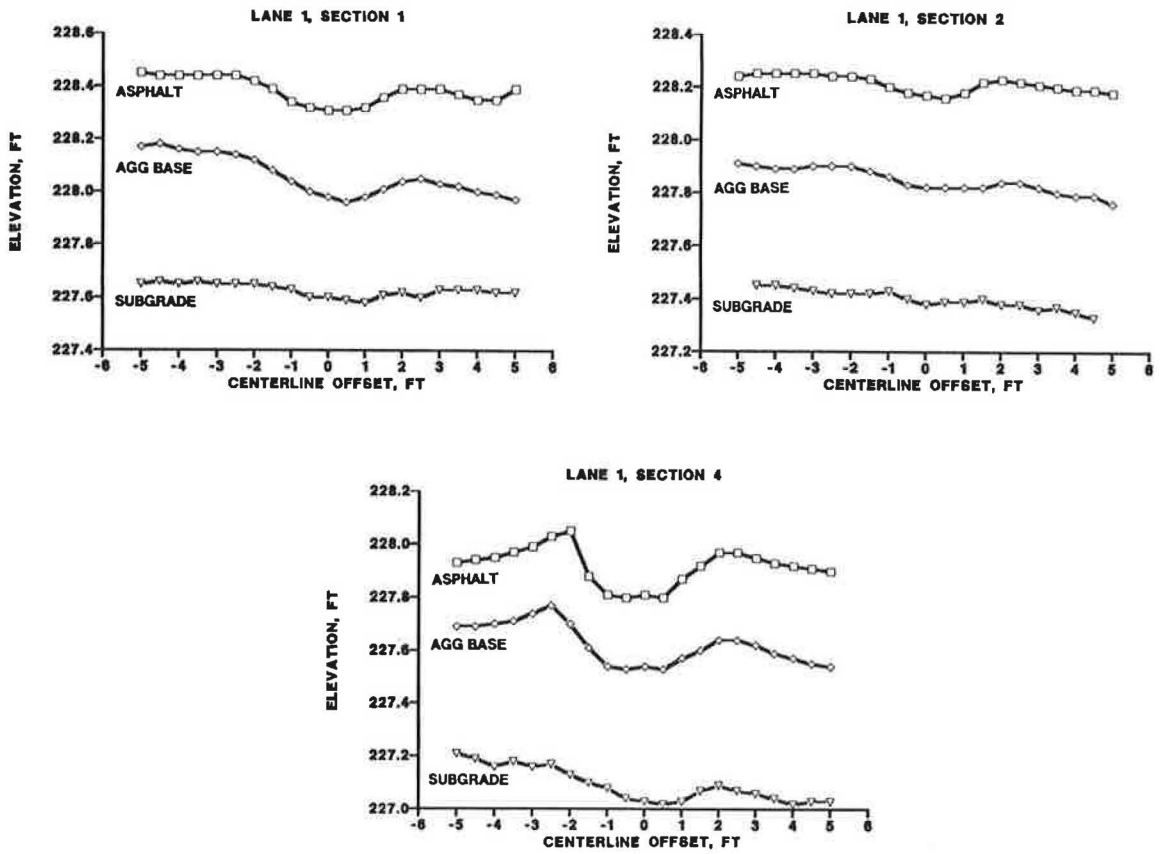


FIGURE 4 Postfailure profiles, PTF Phase 1, Lane 1.

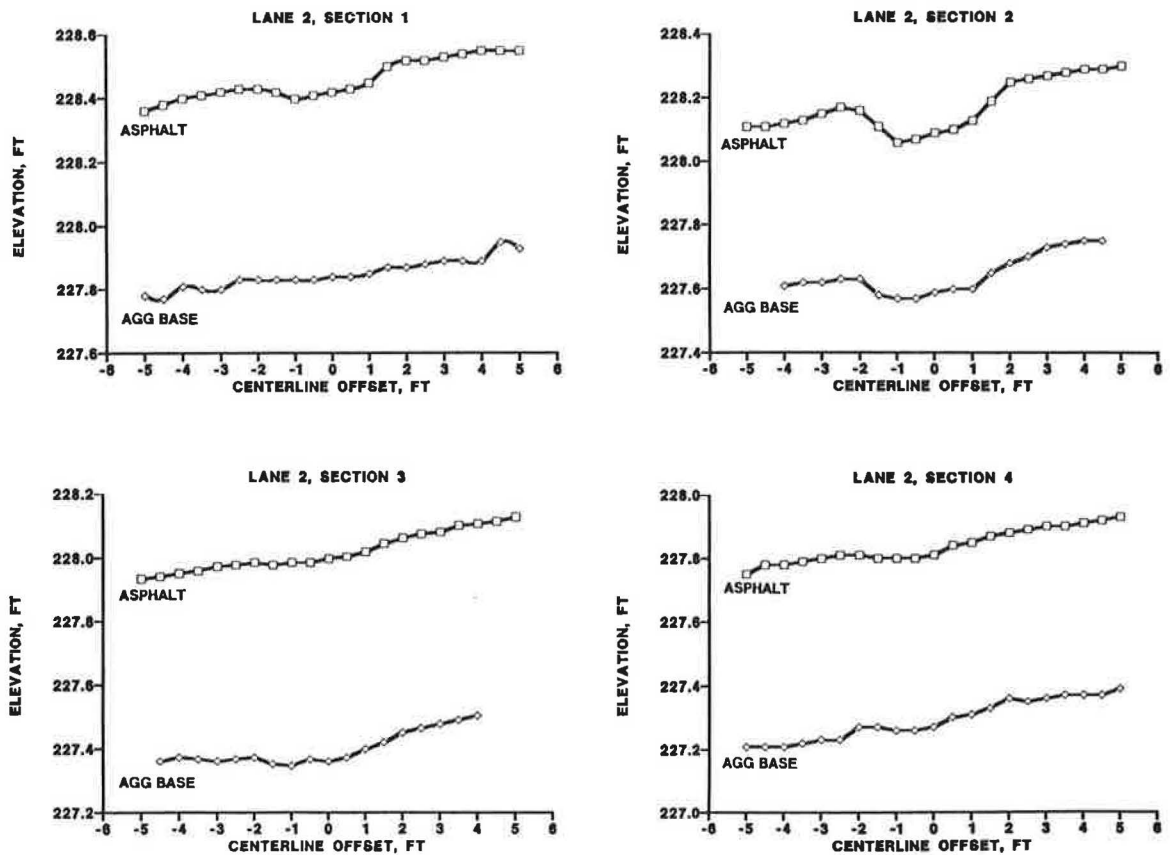


FIGURE 5 Postfailure profiles, PTF Phase 1, Lane 2.

TABLE 5 Material Properties, Montana and Wyoming Field Tests

Subgrade and Base				
Property	Montana		Wyoming	
	Subgrade	Base	Subgrade	Base
Classification	A-4(1)	A-1-a	A-6(10)	Cement Treated
Strength	R Value 32	R Value 80	R Value 5	3421 psi
Average In-Situ Density	118.7 pcf	133.9 pcf	113.3 pcf	NT <sup>a</sup>
	98% AASHTO T-99	96% AASHTO T-180	95 % AASHTO T-99	
Average In-Situ Moisture				
Before ALF Testing	11.1%	4.4%	16.6%	NT
After ALF Testing	13.4%	4.3%	16.0%	NT
Resilient Modulus <sup>b</sup>	NT	NT	10327 $\sigma_d^{-.36}$	NT

Asphalt Concrete			
Property	Montana		Wyoming
	Anitrut	Original	Surface
Asphalt Cement	85/100 Pen	120/150 Pen	AC-20
Resilient Modulus, ksi <sup>c</sup>			
55 °F	1560	1710	NT
73 °F	479	695	NT
90 °F	51	169	NT
Average Air Voids			
Before ALF Testing	2.75%	3.10%	5.65%
After ALF Testing	2.10%	3.30%	4.68%
Average Asphalt Content	5.70%	5.90%	5.39%

<sup>a</sup> Not Tested  
<sup>b</sup> Models yield  $M_r$  is psi for stresses in psi  
 $\sigma_d$  = deviatoric stress  
<sup>c</sup> From indirect tension tests

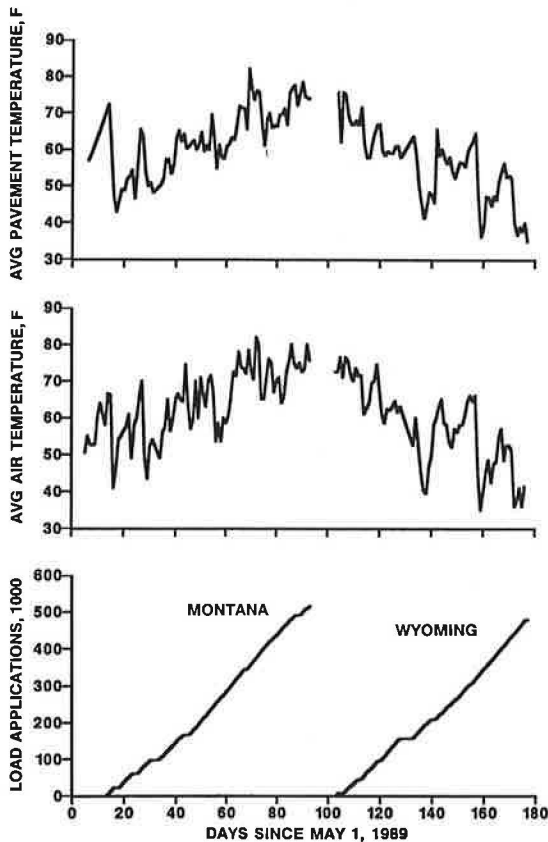


FIGURE 6 Loading history and environmental conditions, Montana and Wyoming field tests.

tive of the response experiment was to assess the relative damage potential of wide-based single tires through an analysis of pavement responses (strains and deflections). The objective of the performance experiment was to assess the relative damage potential of wide-based single tires through a comparative analysis of pavement performance. Only the comparative performance tests on Lane 2, Section 1, and Lane 3, Section 1, were completed during the time frame covered by this paper.

*Test Sections and Material Properties*

The design cross section for Lane 1, Section 4, the OECD cross-test section, consisted of a 2.0-in. asphalt concrete surface course and a 3.0-in. asphalt concrete binder course over a 12.0-in. crushed aggregate base. The design cross section for Section 1 of Lanes 2 and 3, which was used in the dual-versus single-tire performance test, was a 1.0-in. asphalt concrete surface course and a 2.5-in. binder course over a 12.0-in. crushed aggregate base. The aggregate base and the subgrade soil were the same as those in the PTF Phase 1 tests. Table 7 presents material properties for the asphalt concrete used in the Phase 2 test sections.

*Pavement Performance Results and Findings*

Figure 8 presents the loading and temperature histories for the Phase 2 tests. The OECD section was tested with a load of 14,100 lb on dual 11R22.5 radial tires inflated to 100 psi.



TABLE 6 Performance Summary: Montana and Wyoming Field Tests

Test Section	Date	No. of Passes	Slope Variance (10 <sup>-4</sup> )	Avg Rut Depth (in)	Avg Cracking (%) <sup>a</sup>	PSI Loss
I-90, Montana						
	5/10/89	0	4.70	0.19	0	0.00
	5/16/89	31750	4.80	0.19	0	0.01
	5/22/89	63338	5.30	0.19	0	0.08
	5/31/89	103118	5.50	0.19	0	0.11
	6/ 6/89	148133	5.50	0.19	0	0.11
	6/13/89	181353	6.10	0.28	0	0.24
	6/20/89	238786	6.20	0.33	0	0.29
	6/27/89	293464	6.00	0.33	0	0.27
	7/ 5/89	354227	6.60	0.45	0	0.47
	7/11/89	403003	7.10	0.59	0	0.72
	7/18/89	454496	8.50	0.62	0	0.91
	7/28/89	514480	8.50	0.71	0	1.08
I-90, Wyoming						
	8/ 7/89	0	2.60	0.00	0	0.00
	8/15/89	34667	2.70	0.00	0	0.02
	8/22/89	79392	2.60	0.00	0	0.00
	8/29/89	127599	3.00	0.00	0	0.09
	9/ 6/89	154946	2.60	0.00	0	0.00
	9/12/89	197022	2.90	0.00	0	0.07
	9/20/89	243822	2.70	0.00	0	0.02
	9/27/89	292295	2.80	0.00	0	0.04
	10/ 3/89	340159	2.80	0.00	0	0.04
	10/10/89	395750	3.20	0.00	0	0.13
	10/20/89	477737	3.50	0.05	0	0.19

<sup>a</sup> Based on total pavement width. For wheelpath cracking multiply by 1.5.

The dual- and single-tire tests used a load of 12,000 lb and 102-psi tire pressure. Lane 2, Section 1, was tested with dual 11R22.5 tires, and Lane 3, Section 1, was tested with a 425/65R22.5 wide-based single tire. During the conduct of these tests, the ALF was alternated between the two test sections to minimize environmental effects. On the basis of tests at the time of construction and during the postfailure investigation, there was no significant difference in subgrade or base course moisture between the dual- and single-tire performance sections.

The results of the Phase 2 performance tests are summarized in Table 8. The test for each of these sections was stopped

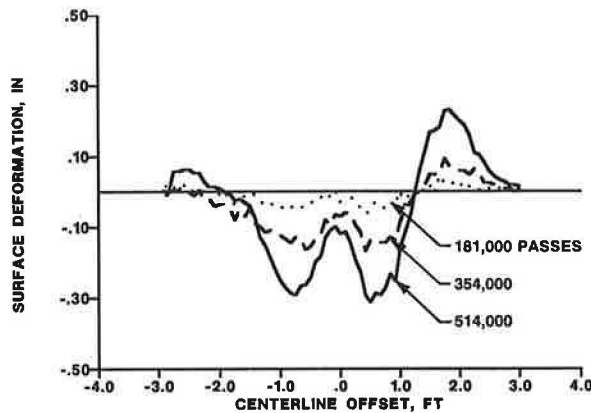


FIGURE 7 Typical transverse profile, Montana test section.

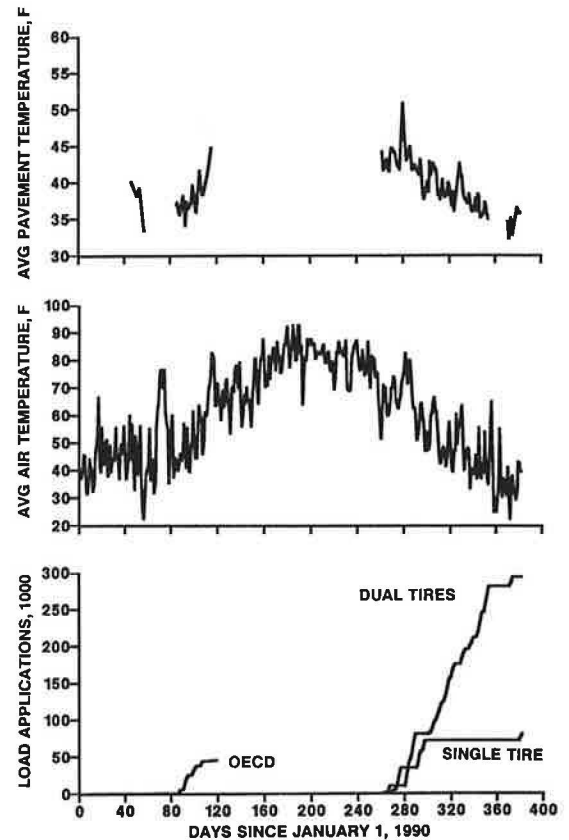


FIGURE 8 Loading history and environmental conditions, PTF Phase 2.

TABLE 7 PTF Material Properties, Phase 2

Asphalt Concrete				
Property	Section 1, Lanes 2&3		Section 4, Lane 1	
	Binder	Wearing	Binder	Wearing
Asphalt Cement	AC-20	AC-20	AC-20	AC-20
Resilient Modulus, ksi <sup>a</sup>				
41 °F	1770	1267	1413	1152
77 °F	267	199	244	239
104 °F	37	36	40	40
Average Air Voids	2.60%	7.04%	4.20%	8.90%
Average Asphalt Content	4.72%	5.69%	4.40%	5.60%

<sup>a</sup> From indirect tension tests

upon initiation of fatigue failure in the test section. Fatigue failure was identified by a sharp increase in the observed cracking in the test section. Fatigue failure of the OECD section occurred after 34,000 load applications. A comparison of the performance data for this section with that obtained on a pavement of similar cross section at the Nantes facility will be performed as part of the FORCE project. For the dual- versus single-tire performance test, the wide-based single tire proved to be significantly more damaging to thin asphalt pavements. The fatigue life of the single-tire section was

approximately one-fourth that for the dual-tire section, and the rutting under the single tire was approximately twice that for the comparable dual tires.

Figure 9 presents layer profiles obtained from the Phase 2 postfailure testing. No rutting in the subgrade was observed for these tests; therefore, only the profiles for the pavement surface and the surface of the crushed aggregate base course are shown. Like the PTF Phase 1 tests, the majority of the rutting occurred in the crushed aggregate base layer. The permanent deformation in the asphalt layer was small for all three tests.

TABLE 8 Performance Summary: PTF Phase 2 Research

Test Section	Date	No. of Passes	Slope Variance (10 <sup>-6</sup> )	Avg Rut Depth (in)	Avg Cracking (%) <sup>a</sup>	PSI Loss
Lane 1, Section 4						
	1/10/90	0	4.69	0.00	0	0.00
	2/21/90	104	4.65	0.03	0	0.00
	2/21/90	113	4.51	0.04	0	0.00
	2/27/90	231	4.40	0.06	0	0.00
	3/29/90	1103	4.68	0.12	0	0.02
	3/30/90	5103	4.64	0.13	0	0.02
	4/ 3/90	10103	4.72	0.19	0	0.06
	4/ 4/90	19103	4.77	0.29	0	0.17
	4/ 5/90	24103	5.22	0.35	1	0.32
	4/11/90	34103	6.96	0.49	13	0.72
	4/18/90	44103	10.44	0.61	28	1.27
	4/26/90	45140	10.91	0.62	28	1.32
Lane 2, Section 1						
	9/18/90	0	6.90	0.00	0	0.00
	9/21/90	1000	9.56	0.09	0	0.25
	9/25/90	5000	10.62	0.10	0	0.33
	9/27/90	10000	11.60	0.11	0	0.40
	10/12/90	35000	16.17	0.16	0	0.68
	10/18/90	80000	21.10	0.19	0	0.90
	11/ 9/90	119846	21.85	0.21	0	0.94
	11/16/90	153188	24.50	0.21	0	1.03
	11/30/90	193897	27.42	0.24	0	1.14
	12/14/90	236256	54.19	0.24	4	1.76
	1/ 7/90	280000	80.20	0.34	9	2.19
	1/15/90	293017	150.68	0.41	10	2.78
Lane 3, Section 1						
	9/27/90	0	4.64	0.00	0	0.00
	9/27/90	1000	5.62	0.10	0	0.15
	10/ 1/90	5000	11.73	0.18	0	0.72
	10/ 2/90	10000	11.85	0.20	0	0.74
	10/ 8/90	34120	24.67	0.27	0	1.36
	10/29/90	71044	39.46	0.36	0	1.83
	1/21/90	79456	102.73	0.51	9	2.87

<sup>a</sup> Based on total pavement width. For wheelpath cracking multiply by 1.5.

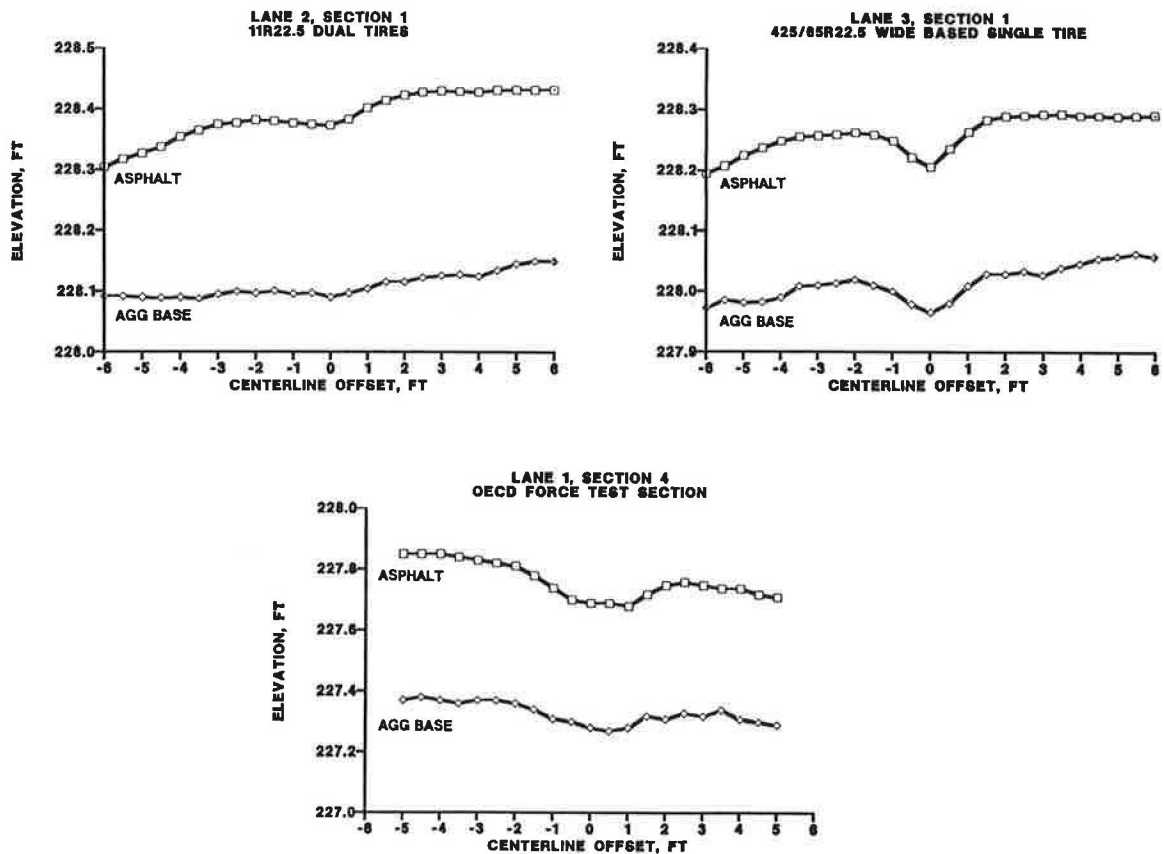


FIGURE 9 Postfailure profiles, PTF Phase 2.

## SUMMARY AND CONCLUSIONS

FHWA has been conducting accelerated pavement performance tests using the ALF machine since August 1986. Tests have been conducted at the PTF as well as at field sites in Montana and Wyoming. During the PTF Phase 1 research, much of the early work was directed at the establishment of operating and data collection procedures for the ALF and the PTF. Once these procedures were established, several accelerated pavement performance tests were conducted to assess the rationality of data obtained with the ALF. These tests showed that performance data obtained with the ALF followed the general trends observed through monitoring of various test roads and in-service pavements. The ALF and the instrumented PTF pavements were also used to study the effect of increased tire pressure.

The field testing program demonstrated the mobility of the ALF and experience with site preparation, traffic control, and site restoration was obtained. This experience was very important, because some of the future research studies identified for the ALF, particularly those associated with maintenance and rehabilitation, require the use of in-service pavements. The Montana field test was an excellent example of the benefits of accelerated pavement testing. During this 3-month test, the rutting performance of an asphalt mixture specifically designed to resist rutting was evaluated. This evaluation showed that the use of the antirutting mixture may delay the development of rutting, but that plastic flow, which has been identified as the major cause of severe rutting, was not eliminated.

Additional mixture design research combined with verification through accelerated testing is definitely needed.

The current Phase 2 research at the PTF demonstrated the comparative testing capabilities of the ALF. In this experiment, the control was the dual-tire loading and the treatment was the wide-based single-tire loading. Findings to date show the wide-based single tire to be significantly more damaging to flexible pavements than conventional dual tires. During the PTF Phase 2 research, techniques were developed to eliminate environmental effects during comparative testing. Future ALF research will emphasize the use of comparative testing in the evaluation of pavement materials and pavement sections.

The above conclusions are based on the stated objectives of the various research programs. An additional use of the performance data presented in this paper is the validation of mechanistic-empirical pavement analysis concepts. Each test represents a valid observation of pavement performance for the materials, loading conditions, and environment encountered. These data should be useful in a variety of validation and model development efforts.

## ACKNOWLEDGMENT

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