Comparison of Results Obtained from the LCPC Rutting Tester with Pavements of Known Field Performance

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In France the Laboratoire Central des Ponts et Chaussees (LCPC) rutting tester has been used successfully for 15 years to prevent rutting. The Colorado Department of Transportation and the FHWA's Turner-Fairbank Highway Research Center were selected to demonstrate this equipment in the United States. Thirty-three sites across Colorado, with either good or poor rutting performance and various temperature and traffic conditions, were selected. Test results indicated that applying the French specification and the LCPC rutting tester was proved too severe for many of the temperature and environmental conditions in Colorado. However, once the testing temperature was adjusted to match the highest on-site temperature, the LCPC rutting tester did an excellent job of predicting pavement performance. The results from the LCPC rutting tester also had excellent correlation with actual rutting depths when temperature and traffic levels were considered.

In September 1990, a group of individuals representing AASHTO, FHWA, National Asphalt Pavement Association, Strategic Highway Research Program, Asphalt Institute, and TRB participated in a 2-week tour of 6 European countries. Information concerning the tour has been published in the "Report on the 1990 European Asphalt Study Tour" (*1*). Several potential improvements of asphalt pavement technology were identified on tour, including adoption of the performance-related testing equipment used in several European countries. French equipment was distributed commercially and marketed, so it was a natural choice for demonstration in the United States. The Colorado Department of Transportation and the FHWA Turner-Fairbank Highway Research Center were selected to demonstrate the testing equipment.

The Laboratoire Central des Ponts et Chaussees (LCPC) rutting tester has been used successfully to prevent rutting in France for 15 years (*2*). However, traffic and terrain in France are extremely different than they are in Colorado. Therefore, first priority was to verify the predictive capabilities of the LCPC equipment by performing tests on mixtures of known field performance in Colorado. Samples of hot mix asphalt pavements, with either a history of rutting or of good performance, were identified and tested with the LCPC rutting tester. An analysis of the LCPC rutting tester's results for pavements with known performance is presented in a detailed report by Aschenbrener (*3*).

EQUIPMENT DESCRIPTION

A full description of the French hot mix asphalt (HMA) design methodology and equipment operation, as followed by the LCPC, is provided by Bonnot (*4*). A brief description of the LCPC rutting tester, its operation, and typical results is provided here.

Testing Equipment and Procedure

To evaluate resistance to permanent deformation, the LCPC rutting tester (Figure 1) is used on a confined slab. The slab is 50 by 18 cm (19.7 by 7.1 in.) and can be 50 to 100 mm (2.0 to 3.9 in.) thick. A 100-mm thick slab has a mass of 20 kg (44 lb).

Two slabs can be tested simultaneously. The slabs are loaded with 5000 N (1,124 lb) by a pneumatic tire inflated to 600 kPa (87 psi). The tire loads the slab at 1 cycle per second; one cycle is two passes. The chamber is typically heated to an air temperature of 60°C (140°F) but can be set to any temperature between 35°C and 60°C (95°F and 140°F).

When a test is performed on a laboratory compacted slab, the slab is aged at room temperature for as long as 7 days. It then is placed in the LCPC rutting tester and loaded with 1,000 cycles at room temperature. The deformations recorded after the initial loading are the "zero" readings. The sample is then heated to the test temperature for 12 hr before the test begins. Rutting depths are measured after 100; 300; 1,000; 3,000; 10,000; 30,000; and possibly 100,000 cycles. The rutting depth is reported as a percentage of the slab thickness. The percentage is calculated as the average of 15 measurements (five locations along the length times three along the width) divided by the slab's original thickness. A pair of slabs can be tested in about 9 hr.

Test Results

The results are plotted as rutting depth over cycles on log-log graph paper. The slope and intercept (at 1,000 cycles) are calculated using linear regression:

$$Y = A\left(\frac{X}{1{,}000}\right)^{B} \tag{1}$$

where

Y = rutting depth in percent,
X = cycles,
A = intercept of rutting depth at 1000 cycles, and
B = slope of curve.

French Specifications

French specifications for the test are reported in detail elsewhere (*2*). In France, a successful test typically will have a rutting depth

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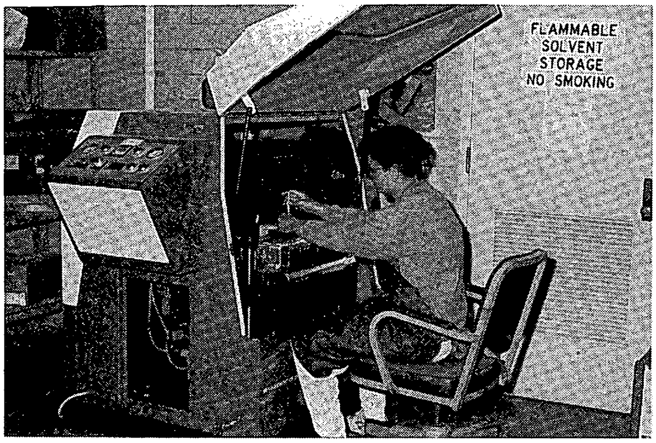

FIGURE 1 Measuring rutting depths on LCPC rutting tester.

that is less than or equal to 10 percent of the slab thickness after 30,000 cycles. The test always is performed at 60°C. The thickness of the slab tested is controlled by the thickness of the overlay.

The French indicate that there are no reports of rutting on highways in which the HMA has passed the test (*2*). In the few cases where rutting did occur, problems were identified that included the following: the HMA failed the original design, an improper test procedure was used with the LCPC rutting tester, or the HMA placed on the project varied from the HMA used in the design during production.

STUDY APPROACH

Three options were considered for comparing the LCPC rutting tester results to pavements of known field performance. One was selected to provide initial field performance validation, it is Option 2, reported in this study.

Option 1

Option 1 would be to design and build pavements that would either pass or fail the LCPC rutting tester and then monitor their performance. Whereas this method will be performed and will be the primary method of validating the LCPC rutting tester, results may not be available for 5 years.

Option 2

Option 2, like the third option that follows, involves testing HMA that was placed in the past but has a known performance. Option 2 would test field cores and slabs and would involve testing HMA with an aged asphalt cement. The primary cause of rutting in Colorado is not the asphalt cement stiffness but the change in properties that occurs between the time of HMA design and construction (*5*). The error in using Option 2 was considered minimal; it is reported in this study.

Option 3

Option 3 would involve obtaining the original raw materials and blending them to match the original job mix formula of pavements of known field performance. Option 3 would not reflect changes that could have occurred during actual production or changes in aggregate sources and asphalt cements during the past 5 to 10 years. Because most rutting in Colorado is considered to involve HMA that was constructed with different properties than were designed, the error would be large. The third option was not investigated.

SITE SELECTION

Temperature

High-temperature environment was defined as the highest monthly mean maximum temperature (HMMMT), i.e. the average of the daily high temperatures in the hottest month of the year. Three high-temperature environments exist in Colorado.

Traffic

The levels of traffic are commonly defined according to the number of equivalent 18-kip single-axle loads (ESALs) during the design life of the pavement. Six levels of traffic were selected. The traffic levels used in this report were determined from the network level pavement-management data that report the equivalent daily 18-kip load applications (EDLAs). Traffic measurement is highly variable, so just EDLA was used since there is confidence in the current values. EDLA was selected to provide a relative comparison of traffic loading for each site analyzed.

Performance

Well performing pavements and pavements exhibiting rutting were selected. Pavements rutting less than 5 mm (0.2 in.) were considered good. Rutting depths reported by Colorado's network level pavement management program are from the ARAN system that measures ruts with a laser beam. Ruts were also measured with a 2-m straight edge.

Only those sites that exhibited rutting from plastic flow were used. Sites that had rutting because of subgrade failure, stripping, or improper compaction were eliminated from the study. Additionally, sites at intersections or which included climbing lanes for trucks on steep grades also were eliminated. In short, the study was confined to sites that had rutted from plastic flow under normal highway speeds, 73 to 105 km/hr (45 to 65 mph).

Colorado experience suggests that pavements typically rut within the first 3 to 5 years after construction. Further, there is a high probability that pavements that do not rut in the first 3 to 5 years will not rut throughout their service life. The well performing pavements selected for this study were over 6 years old.

Final Site Selection

At least one rutting and non-rutting site from most traffic levels and temperature environments in Colorado were selected, as indicated in Table 1. Additional sites were selected that corresponded to a majority of Colorado's interstate conditions. A total of 33 sites was evaluated. They are listed in Table 2 and the vicinity of each test site is indicated in Figure 2.

TABLE 1 Summary of Sites by Traffic and Environmental Conditions

	Highest Mean Monthly Maximum Temperature		
EDLA	< 27°C	27° to 32°C	32° to 38°C
< 27	---	19, 20	25, 26
27 - 82	33	27, 28	23, 24
82 - 274	31, 32	5, 6	21
274 - 822	17, 18	7, 8	15, 34, 35
822 - 2740	36,37	3,4,11,12,13,14	9, 10
2740 - 8220	---	29, 30	---

SAMPLING AND TESTING

Cores and slabs were obtained from each site. Slabs were sawed between the wheel paths, and parallel to the direction of travel. Three slabs were obtained at each location. Five 100-mm (4-in.) diameter cores were obtained between the wheel paths, and three were obtained in the wheel paths. The thickness of lifts at each site was identified by observing and measuring the slabs.

The results of the forensic investigation are reported by Aschenbrener (*5*), including testing aggregate, asphalt cement, and HMA properties.

RESULTS AND DISCUSSION OF TESTING

Three slabs were obtained at each site for testing in the LCPC rutting tester. One slab was typically tested at 50° (122°F) and another at 60°C (140°F). The third slab was tested at either 40° or 45°C (104°or 113°F) for low temperature sites, and usually at 55°C (131°F) for moderate and high temperature sites.

Typically each slab tested had two to four layers. No attempt was made to separate the layers of the slabs. Each slab was tested as a multiple layer, just as it was in the field. If a lower lift had contributed to rutting, it was detected by the LCPC rutting tester (*6*).

TABLE 2 Site Descriptions

Site	Highway	M.P.	Location	Rut Depth	Temp.	EDLA
3	US-85	251	Platteville	0 mm	31°C	941
4	US-85	248	Platteville	25	31	864
5	SH-66	40	Longmont	0	31	250
6	SH-119	50	Niwot	10	31	221
7	SH-52	12	Dacona	3	31	358
8	SH-52	19	Fort Lupton	18	31	310
9	US-287	430	Lamar	3	36	878
10	US-287	430	Lamar	25	36	878
11	I-25	41	Walsenburg	0	29	1027
12	I-25	35	Walsenburg	20	29	1027
13	I-70	430	Burlington	3	32	1377
14	I-70	445	Burlington	20	32	1336
15	US-50	375	LaJunta	3	34	551
17	US-160	271	LaVeta Pass	13	24	493
18	US-160	278	LaVeta Pass	3	24	465
19	US-389	10	Branson	0	29	3
20	US-389	10	Branson	10	29	3
21	US-50	454	Granada	0	34	270
23	US-160	490	Walsh	3	33	48
24	US-160	486	Walsh	10	33	48
25	SH-55	2	Crook	3	33	20
26	SH-55	1	Crook	13	33	20
27	SH-71	219	Stoneham	0	31	56
28	SH-71	214	Stoneham	18	31	56
29	I-25	237	Denver	8	31	3127
30	I-25	243	Denver	15	31	3127
31	US-40	225	Fraser	10	24	169
32	US-40	216	Granby	3	24	171
33	US-34	2	Granby	13	24	53
34	I-70	15	Fruita	25	34	780
35	US-50	75	Delta	13	34	399
36	I-70	214	Eisenhower	20	22	1137
37	I-70	207	Silverthorne	3	22	1137

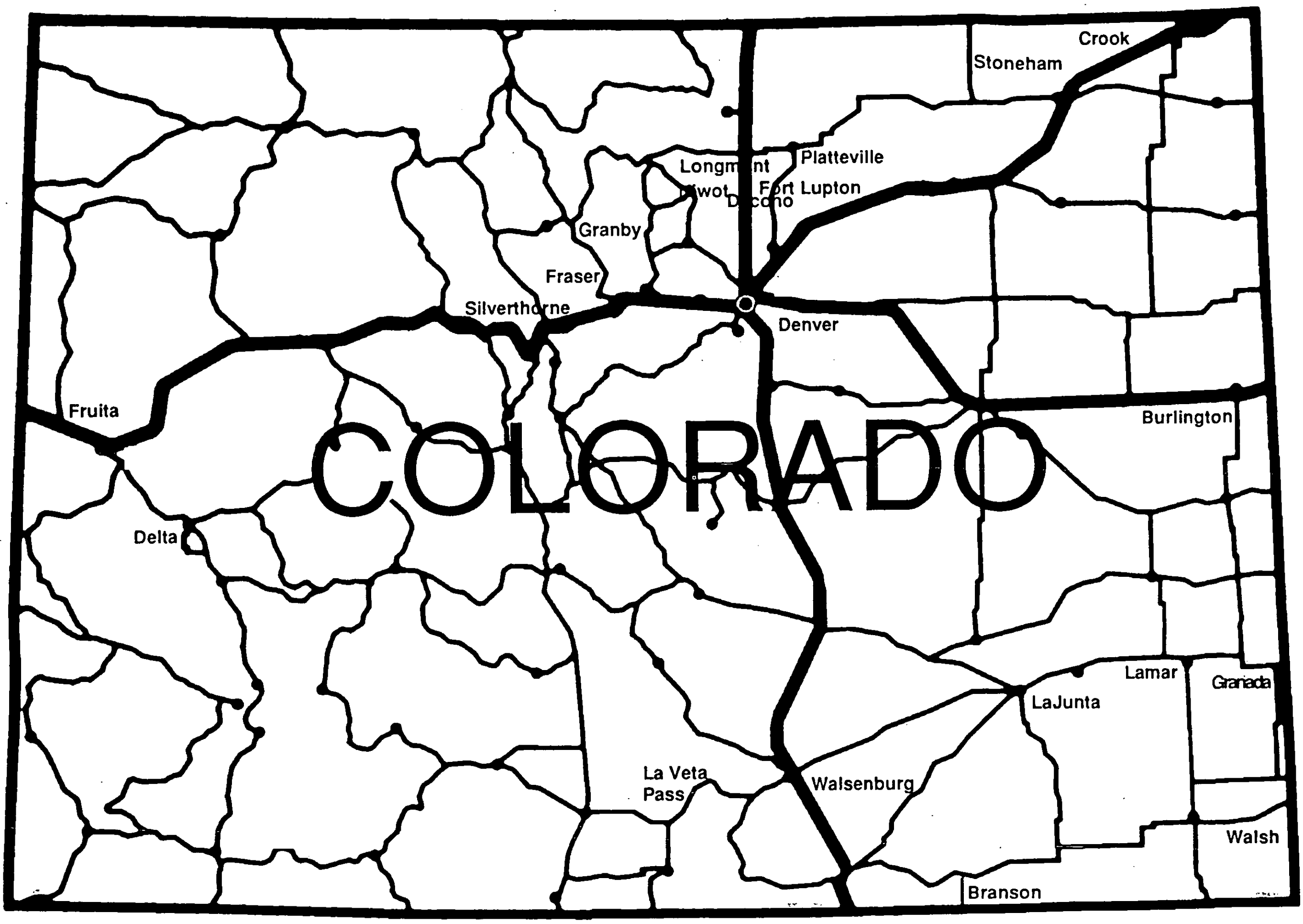

FIGURE 2 Test site locations.

Comparison to the French Specification

An acceptable mix for the pavements tested in this study using the French specification will have a rutting depth of less than or equal to 10 percent of the slab thickness after 30,000 cycles at 60°C. This is a "go, no-go" criteria.

For the 31 Colorado sites tested at 60°C, the comparison of the actual pavement performance versus the specification established by the French is shown in Table 3. Two sites (32 and 36) were not included because the slabs were not tested at 60°C.

The French specification is more severe than is necessary for conditions typically encountered in Colorado. Of the sites tested, there was no rutting in the field for those slabs that passed the test, and sites that had rutted in the field all failed the test. However, several pavements with good performance would have failed the French specification.

Temperature Adjustments

The French use one very severe temperature to perform the test. The method is appropriate to promote a high factor of safety against rutting. However, in order to make the test more representative of the conditions in Colorado, different test temperatures were examined. The testing temperature should simulate the actual pavement temperatures it was thought.

Tests were performed using different testing temperatures. The slope *B*, as defined in Equation 1, is reported along with results from the LCPC rutting tester in Tables 4–6. The rutting depth at 30,000 cycles was reported if the sample survived; those cycles at a 10-percent rutting depth were reported if the test had to be stopped.

High-Temperature Sites

Seven of the 10 high-temperature sites presented in Table 4 performed very well using the "go, no-go" criteria at a 60°C testing temperature. Site 23 at Walsh had very poor performance results from the rutting tester despite the good historical performance of the road. The results from Sites 23 and 24 were not distinguishable from each other, despite their having different performance histories. The sites were from the same project and within 4 mi of each other. It was assumed that this mix was marginal and that some site-specific situation during or after placement caused the difference in rutting in the field.

Site 15 in LaJunta did not meet the LCPC criteria despite good field performance. The pavement had 1.7 percent air voids in the wheel path, and at adjacent locations there is 13 mm (0.5 inches)

TABLE 3 Comparison of Actual Pavement Performance to French Specification Using a 60°C Test Temperature

LCPC Results	Actual Pavement Performance	
	No Rutting	Rutting
Pass	4	0
Fail	11	16

TABLE 4 Summary of Results for High-Temperature Sites

	60°C Test Temp.		55°C Test Temp.		50°C Test Temp.	
Site	Slope (B)	Rut @ 30,000 or cycles @ 10%	Slope (B)	Rut @ 30,000 or cycles @ 10%	Slope (B)	Rut @ 30,000 or cycles @ 10%
25	---	---	0.40	22,000 C	---	---
26	---	---	---	---	0.70	9,000 C
23	0.86	600 C	---	---	0.70	4,000 C
24	0.86	100 C	---	---	0.80	2,000 C
21	0.33	5.5%	---	---	0.35	4.1%
35	1.02	600 C	---	---	0.89	2,000 C
15	0.45	9,000 C	---	---	0.57	29,000 C
34	0.84	3,000 C	---	---	0.69	12,000 C
9	0.34	4.8%	---	---	0.36	7.1%
10	0.73	300 C	---	---	0.40	2,000 C

--- Not Tested
C Cycles to 10% rutting depth
% Rutting depth at 30,000 cycles

TABLE 5 Summary of Results for Moderate-Temperature Sites

	60°C Test Temp.		55°C Test Temp.		50°C Test Temp.	
Site	Slope (B)	Rut @ 30,000 or cycles @ 10%	Slope (B)	Rut @ 30,000 or cycles @ 10%	Slope (B)	Rut @ 30,000 or cycles @ 10%
19	0.37	12,000 C	0.36	7.8%	0.37	9.7%
20	0.96	400 C	*0.93	700 C	0.90	1,000 C
27	0.41	20,000 C	0.28	4.4%	0.31	3.7%
28	1.02	200 C	*1.03	1,000 C	1.03	2,000 C
5	0.71	7,000 C	0.26	3.1%	0.38	2.5%
6	0.74	300 C	*0.72	*1,000 C	0.70	2,000 C
7	0.49	4,000 C	---	---	0.37	6.4%
8	0.89	400 C	*0.82	*700 C	0.75	1,000 C
3	0.55	7,000 C	---	---	0.37	2.9%
4	0.73	500 C	*0.73	*2,000 C	0.74	5,000 C
13	0.41	7.9%	*0.32	*5.5%	0.24	3.0%
14	0.92	200 C	0.55	5,000 C	0.62	3,000 C
11	0.22	5.7%	*0.21	*5.1%	0.21	4.4%
12	1.06	800 C	*0.95	*2,000 C	0.85	3,000 C
C29	0.38	15,000 C	0.44	27,000 C	0.36	3.6%
30	0.60	4,000 C	0.55	6,000 C	0.59	12,000 C

* Estimated value
--- Not tested
C Cycles to 10% rutting depth
% Rutting depth at 30,000 cycles

TABLE 6 Summary of Results for Low-Temperature Sites

	50°C Test Temp.		45°C Test Temp.		40°C Test Temp.	
Site	Slope (B)	Rut @ 30,000 or cycles @ 10%	Slope (B)	Rut @ 30,000 or cycles @ 10%	Slope (B)	Rut @ 30,000 or cycles @ 10%
33	0.85	5,000 C	0.77	8,000 C	0.46	5.5%
32	0.33	4.7%	0.35	4.3%	0.44	4.1%
31	0.62	5,000 C	---	---	0.60	3.9%
18	0.66	8,000 C	0.53	17,000 C	---	---
17	0.79	3,000 C	0.71	9,000 C	0.75	9,000 C
37	0.37	3.8%	---	---	0.30	1.9%
36	0.29	6.1%	0.29	5.3%	0.30	4.3%

--- Not tested
C Cycles to 10% rutting depth
% Rutting depth at 30,000 cycles

rutting depths. Past research had indicated that pavements with less than 3 percent air voids in the wheel path have a high probability of rutting (*7–9*). Even though the pavement did not rut at the location of the sample, the material would not be desirable for use statewide. Results from the LCPC rutting tester indicated that the material was unacceptable.

Mechanical problems developed with the LCPC rutting tester while testing Sites 25 and 26. Therefore only one result from each site was obtained. Site 25 had very low traffic. For low traffic, 10,000 or 20,000 cycles possibly should be specified.

Moderate Temperature Sites

Moderate temperature sites correlated excellently with the LCPC rutting tester at temperatures lower than 60°C. Results are compiled in Table 5 from the pavements placed in moderate temperature areas; they were significantly affected by the testing temperature. By changing the testing temperature from 60°C to 50°C, six sites with good field performance (sites 3, 5, 7, 19, 27, and 29) went from failing to passing laboratory-test results, and no sites with poor performance went from failing to passing.

Site 29 in Denver had an 8 mm (0.3 in.) rutting depth; this is considered slightly unacceptable. At the 55°C testing temperature, the slab failed at 27,000 cycles, short of the required 30,000 cycles. A testing temperature of 55°C would closely represent the actual performance of this pavement.

Because there was no test performed at 55°C for several sites, values were estimated on the basis of results from 50°C and 60°C. No values were estimated for Sites 3 and 5 because there was a large change in results from the 10°C difference in testing temperature.

Low-Temperature Sites

Results for the low-temperature sites are compiled in Table 6. Correlating results with actual pavement performance was highly variable and is believed to be dependent on elevation. It was not always possible to obtain the temperature at the exact site location. The "standard" low-temperature sites (Sites 17, 31, 32, and 33) were below 2400 m (8,000 ft) in elevation and had good correlation at 50°C. Site 18 was at the top of LaVeta Pass at over 3000 m (9,800 ft). For a mix placed at this elevation, the testing temperature that models field performance, possibly 40°C, appears to be much lower than that of the "standard" sites.

Site 36 was in the Eisenhower Tunnel at an elevation of more than 3500 m (11,000 ft). Although the pavement rutted 15 mm (0.6 in.), it was not because of plastic flow; rutting likely occurred because of abrasion from studded tires and tire chains. The voids in the wheel path were 6.4 percent, and the pavement texture was very rough and potholed. This site was not analyzed further.

Comparison to the Modified French Specification

The French specification was modified so that the testing temperatures would match pavement temperatures in the field. The three highest testing temperatures that provided a correlation with the field results were 60°, 55°, and 50°C, respectively, for three different high-temperature areas in Colorado. Table 7 shows acceptable and unacceptable pavement performance as related to the test results, based upon the "go, no-go" specification.

Three sites were not included in Table 7: Sites 3 and 7 did not have a sample tested at the proposed specification temperature, and Site 36 did not rut because of plastic flow.

The four sites that had acceptable field performance but were not acceptable according to the specification and modified test temperatures were Sites 15, 18, 23, and 25. Sites 15 and 23 were discussed with the high-temperature sites and were considered marginally acceptable. Site 18 was at a very high elevation; it possibly should have been tested at 10 degrees Centigrade lower than the modified specification.

Site 25 had very low traffic. Consideration should be given to establishing a testing specification of 10,000 or 20,000 cycles for such low-volume roads. Although the 30,000-cycle criterion worked for Sites 19, 20, 23, 24, 25, 26, 27 and 28, which also had very low traffic, using the 10,000 or 20,000 cycle criterion also would have been appropriate.

Prediction of Rutting Depth

Additional analysis was performed in order to determine whether the LCPC rutting tester could be extended beyond a "go, no-go"

TABLE 7 Comparison of Actual Pavement Performance to French Specification Using Variable Test Temperatures

LCPC Results	Actual Pavement Performance	
	No Rutting	Rutting
Pass	10	0
Fail	4	16

device to forecast actual rutting depths. The results from the LCPC rutting tester used in the analysis were the slope of the rutting curve, B, as defined in Equation 1. The slopes were plotted versus actual pavement rutting depths.

Results indicated that there was a distinct difference between sites with high and low levels of traffic. In all cases, when traffic was divided into two categories, the coefficient of determination increased dramatically. Several entities use 1 million ESALs to differentiate between high and moderate traffic, and that is approximately an EDLA of 250 for 10 years. Regardless of test temperature, there seemed to be slightly better correlation when an EDLA of 400 was used that is approximately 1.5 million ESALs over 10 years.

Furthermore, the best correlations occurred when sites were divided into the different temperature groups. A testing temperature of 60°C was used for high-temperature sites, and 50°C was used for moderate-temperature sites.

On the basis of regression analysis, there was a correlation with the tests from the LCPC rutting tester and actual rutting depths. The forecasting capability was better when traffic volume and site temperatures were considered. The plot shown in Figure 3 is for traffic with an EDLA greater than 400 and a testing temperature of 60°C and 50°C for high- and moderate-temperature sites, respectively. A coefficient of determination, r^2, of 0.87 indicated good correlation. Figure 4 is a plot for traffic with an EDLA of less than 400, and a testing temperature of 60°C and 50°C. A coefficient of determination, r^2, of 0.68 indicated a positive correlation.

CONCLUSIONS

It is understood that the sites tested were old pavements, and that the air voids and asphalt cement had changed since the pavements' original construction. This study provides a preliminary indication of the ability of the LCPC rutting tester to forecast pavement performance.

1. The French specification for the LCPC rutting tester is too severe for many sites in Colorado. Eleven of 15 sites failed the criteria despite good pavement performance. However, no sites that passed the French specification rutted in the field, and all sites that rutted in the field failed the specification.
2. By making slight modifications to the testing temperature, the correlation between the French specification and field performance was greatly improved. Test temperatures of 50°C, 55°C or 60°C (122°F, 131°F or 140°F) for sites in low-, moderate- and high-temperature environments, respectively, were used. For pavements with good performance, 10 out of 14 sites met the French specification at the modified test temperature, and all rutted sites still failed.

Additional adjustments might be considered for extremely low traffic and extremely high altitudes. A requirement of 10,000 to 20,000 cycles might be considered for sites with very low volume. A testing temperature of 40°C (104°F) might be considered for sites at very high elevation.

3. Correlations of the results from the LCPC rutting tester with actual field rutting depths were excellent when the temperature and

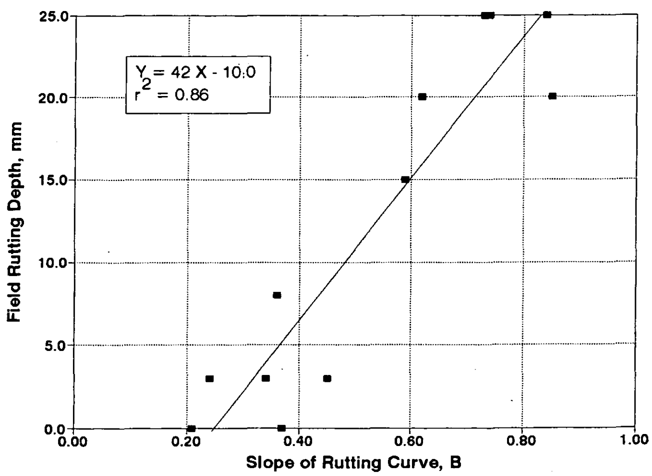

FIGURE 3 Slope from LCPC rutting tester versus actual rutting depths for high-traffic sites using variable test temperatures.

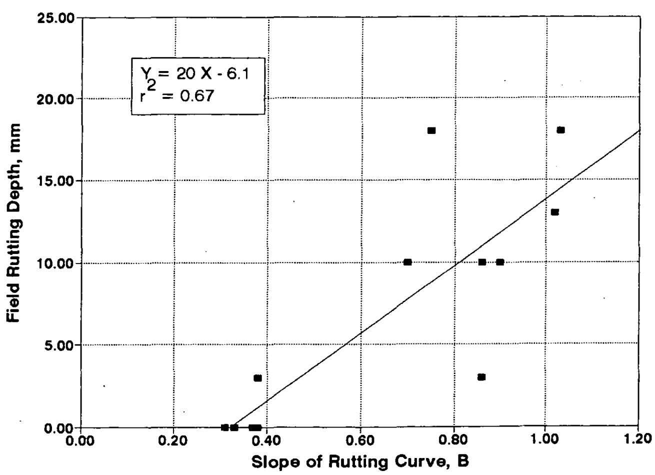

FIGURE 4 Slope from LCPC rutting tester versus actual rutting depths for low-traffic sites using variable test temperatures.

traffic at the site were considered. The best correlation for forecasting actual pavement rutting depths was obtained when two traffic levels (greater and less than an EDLA of 400) and three test temperatures (60°C and 50°C for sites with a Highest Monthly Mean Maximum Temperature of 32°C to 38°C and 27°C to 32°C, respectively) were used.

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