Research Report
KTC-03-05/SPR-245-02-1I

KENTUCKY TRANSPORTATION CENTER

College of Engineering

ANALYSIS OF FIELD PERMEABILITY AND LABORATORY SHEAR STRESSES FOR WESTERN KENTUCKY PARKWAY MILEPOST 18.240 TO MILEPOST 25.565 CALDWELL-HOPKINS COUNTIES

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Research Report
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Analysis of Field Permeability and Laboratory Shear Stresses for Western Kentucky Parkway Milepost 18.240 to Milepost 25.565 Caldwell-Hopkins Counties

by

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16. Abstract

This report lists and discusses results of field permeability tests and laboratory shear tests on samples from a construction project on the Western Kentucky Parkway in Caldwell-Hopkins Counties. Approximately 6,500 tons of asphaltic concrete overlay placed on this project failed to meet minimum density requirements.

Field permeability tests were performed and the results showed that in areas where the mat failed to meet density requirements there was very high permeability in those locations.

The laboratory shear tests also showed that there was a direct relationship between shear strength and density. A linear elastic layer stress analysis also indicated that the shear strength of all of the laboratory tests specimens except one was less than the theoretical stresses that would occur under wheel loadings experienced in the field.

It was concluded that the overlay would probably have a shortened service due to the low densities which would possibly cause excessive raveling and rutting. It was recommended the material be removed and replaced.

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Introduction

In January 2003, the Kentucky Transportation Cabinet requested the Kentucky Transportation Center to study a paving project on the Western Kentucky Parkway, from Milepost 18.240 to Milepost 21.764 in Caldwell County and from Milepost 21.764 to Milepost 25.656 in Hopkins County. The contractor had apparently failed to get minimum density on approximately 6500 tons of asphaltic concrete surface.

Transportation Center personnel collected 12 cores on the project at locations chosen and marked by construction personnel of District 2 of the Kentucky Transportation Cabinet. In addition, six field permeability tests were performed at six of the locations where cores were taken. The permeability readings were obtained by the air induced permeameter (AIP) developed at the Transportation Center. The following table lists the locations where the cores were collected and where the permeability tests were performed. Only six permeability tests were performed because of equipment malfunction.

Table 1. Testing Locations.

Test No.	Station No.	Direction	Lane	Density	Results	Permeability
UK-1	2695+50	WB	Drive	91.6	Pass	X
UK-2	2653+50	WB	Drive	82.9	Fail	X
UK-3	2608+50	WB	Drive	90.7	Pass	
UK-4	2568+00	WB	Drive	85.5	Fail	X
UK-5	2422+00	WB	Drive	91.5	Pass	X
UK-6	2348+50	WB	Drive	83.6	Fail	X
UK-7	2366+50	EB	Pass	82.8	Fail	X
UK-8	2404+00	EB	Pass	92.8	Pass	
UK-9	2560+00	EB	Pass	85.5	Fail	
UK-10	2601+00	EB	Pass	90.6	Pass	
UK-11	2640+44	EB	Pass	88.9	Fail	
UK-12	2683+50	EB	Pass	93.1	Pass	

Permeability Testing and Results

As previously stated, six permeability tests were performed in the field using the AIP device developed at the Transportation Center. Figure 1 shows the device in operation.

Figure 1. AIP Permeameter in Operation.

The results of the permeability testing are Listed in Table 2.

Table 2. Results of Field Permeability Testing

Test No.	Density	Vacuum (mm Hg)	Permeability (ft./day)
UK-1	91.6	260	45
UK-2	82.9	84	261
UK-4	85.5	144	113
UK-5	91.5	456	19
UK-6	83.6	168	89
UK-7	82.8	48	623

Figure 2. is a graphical representation of the results listed in Table 2. From Figure 2, it is clear that the permeability of the asphalt mat is highly dependent on the density. Those locations that fail the density requirement clearly have a much higher permeability than those that pass the minimum density requirement.

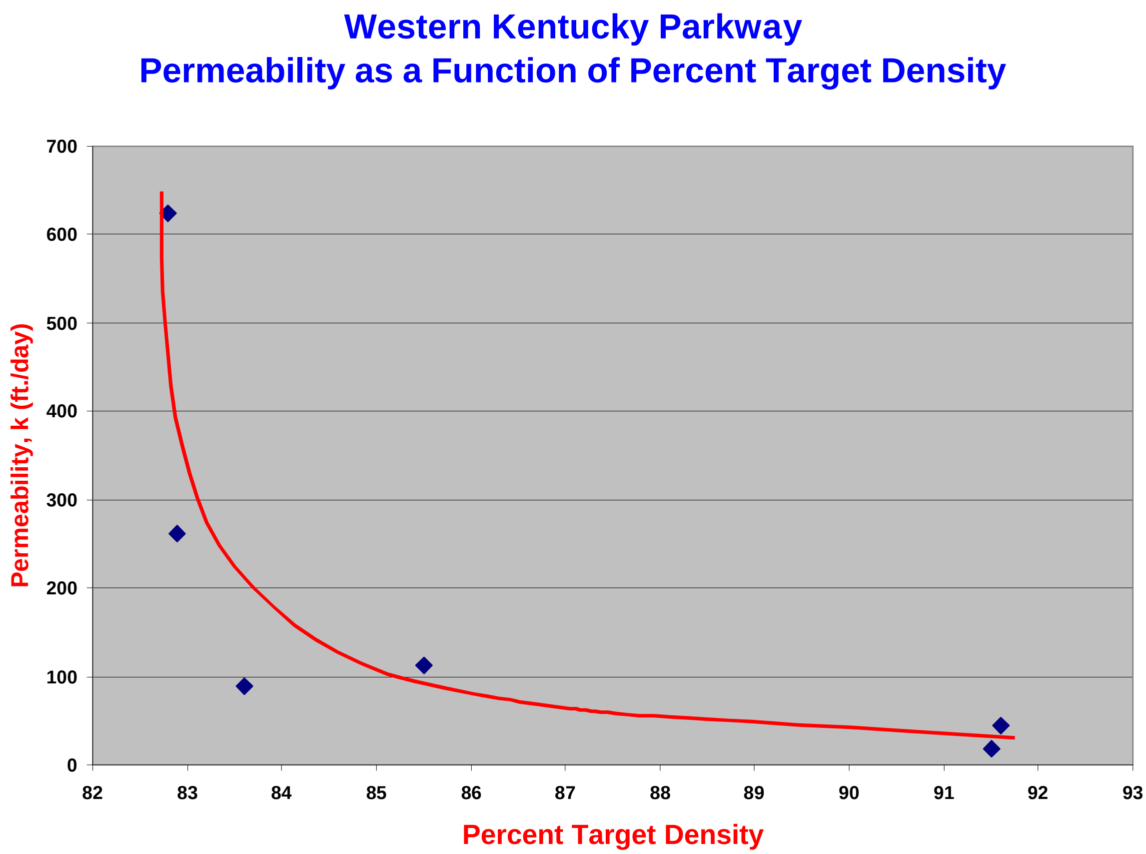

Figure 2. Permeability as a Function of Target Density.

Direct Shear Testing and Results

Cores of the surface material that were collected in the field were tested in the laboratory in direct shear mode. A modified Karol-Warner direct shear box was used. The samples were tested in an environmental chamber at a constant temperature of 104 ^{O}F. The samples were preconditioned for 24 hours at that temperature. Figure 3 shows the shear sample after testing. Figure 4 shows the testing setup.

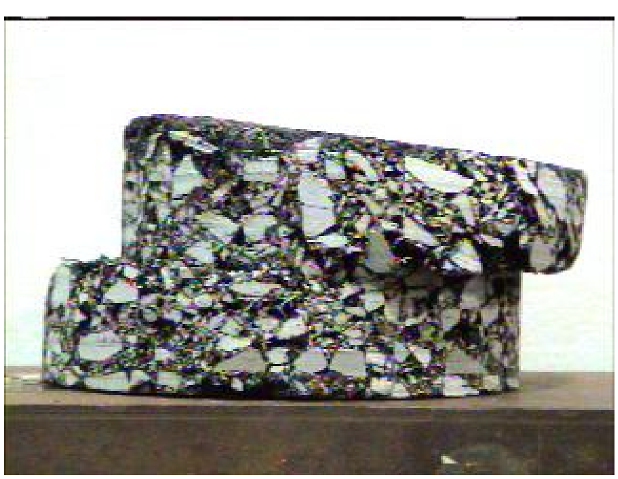

Figure 3. Sample After Testing

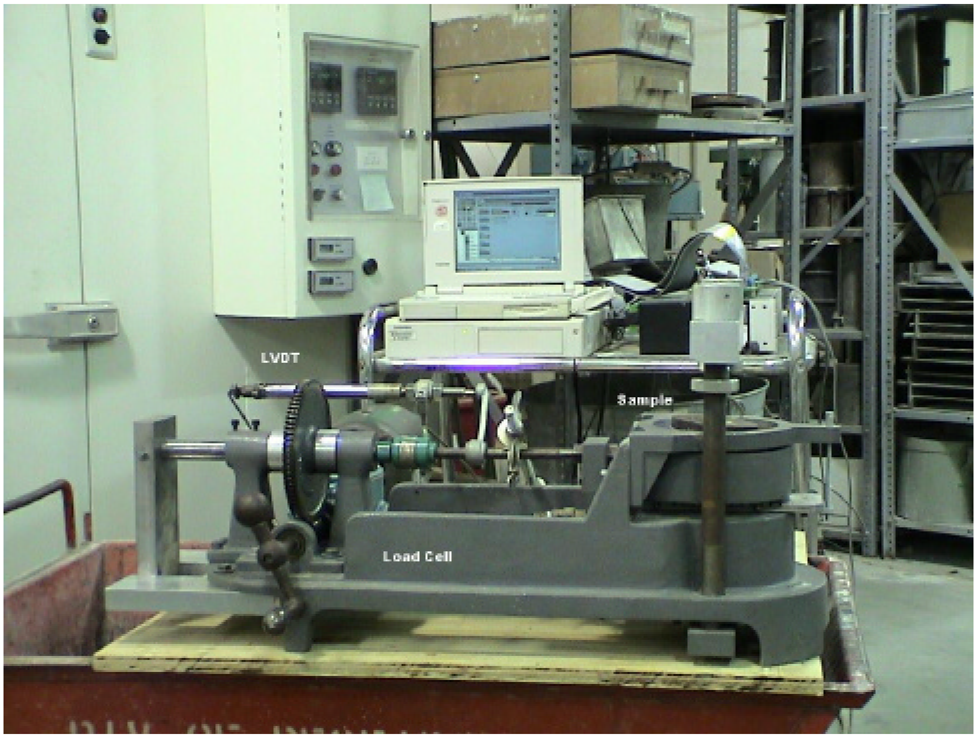

Figure 4. Setup of Testing apparatus.

The results of the shear tests are listed in Table 3 and are shown in Figure 5.

Table 3. Results of Laboratory Shear Tests

Test No.	Density	Results	Maximum Shear Stress (psi)	Comments
UK-1	91.6	Pass	106	
UK-2	82.9	Fail		Bad Test
UK-3	90.7	Pass	105	
UK-4	85.5	Fail	80	
UK-5	91.5	Pass	104	
UK-6	83.6	Fail	90	
UK-7	82.8	Fail		
UK-8	92.8	Pass	118	
UK-9	85.5	Fail	79	
UK-10	90.6	Pass	105	
UK-11	88.9	Fail	90	
UK-12	93.1	Pass	106	

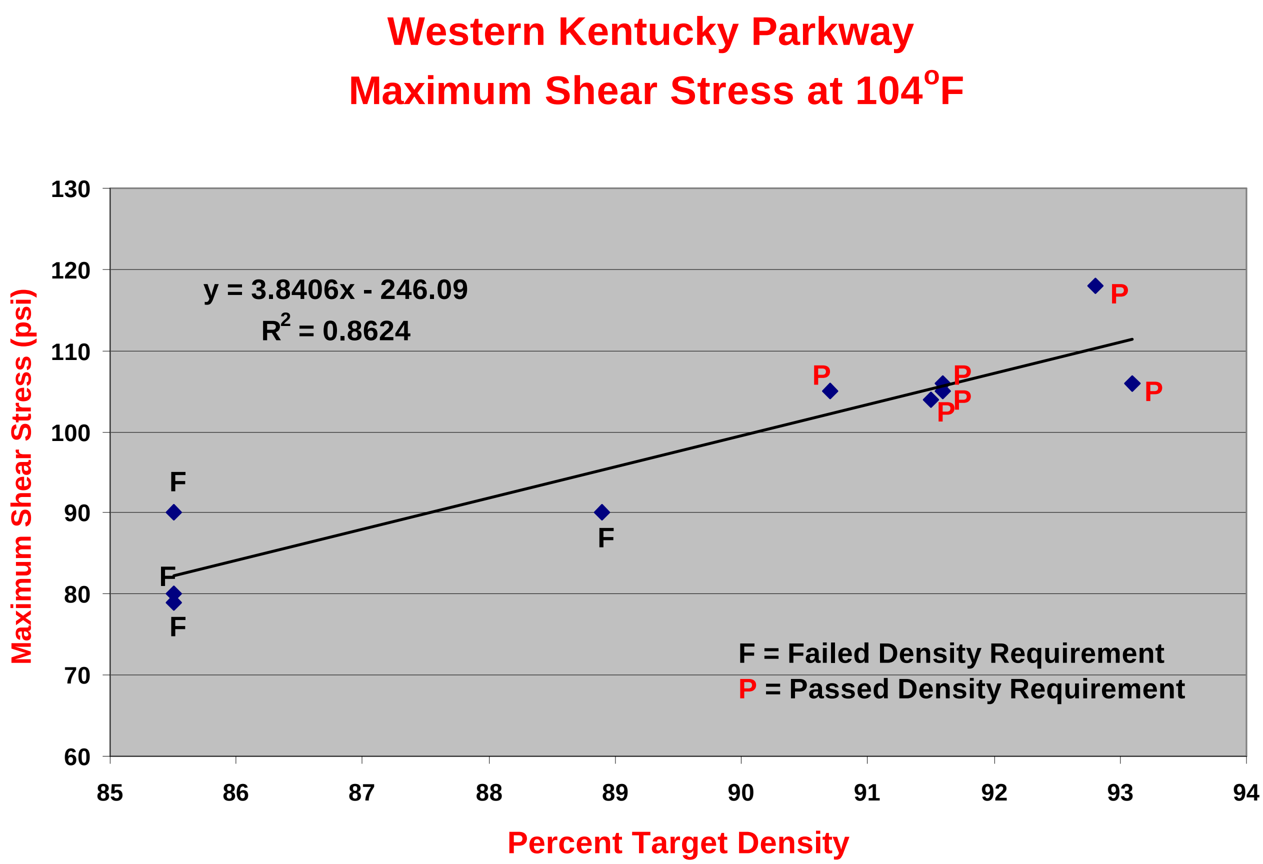

Figure 5. Results of Laboratory Shear Tests.

The state specification for lane density requires a minimum of 90 percent of target density. If the contractor fails to reach that density, the material is to be removed. Figure 5 shows a good correlation between density and maximum shear stress. All of the tests on samples passing the minimum density requirement showed considerably higher shear strength than the samples that failed in density.

A layered elastic stress analysis was performed using the computer program *EVERSTRESS© 5.0*, to determine if the shear strengths from the laboratory tests were higher than stresses that would be experienced in the field from traffic loadings. The results of that analysis are shown in Table 4. The numbers highlighted in yellow are of particular interest. The analysis was performed for one wheel load at an average truck tire pressure of 120 pounds per square inch. The stresses were calculated directly under the load (X-position = 0, Y-position = 0) and at depths of 0.1, 0.5, 1.0, 1.5, 2.5 inches.

Figure 6 shows the same information as Figure 5 with the exception that the calculated stresses at the various depths are plotted on the graph. That figure shows that the stresses in the horizontal directions (S_{XX} and S_{YY}) and in the vertical direction (S_{ZZ}) exceed the maximum stresses obtained from the laboratory tests. This indicates that rutting or wheelpath consolidation will most likely be a problem with warmer temperatures.

Table 4. Results of Layered Elastic Stress Analysis

No of Layers: 4   No of Loads: No of X-Y Evaluation Points: 1

Layer *	Poisson's Ratio	Thickness (in)	Moduli(1) (ksi)
1	0.35	15	360
2	0.35	10	100
3	0.4	6	50
4	0.45	*	5

Load No	X-Position (in)	Y-Position (in)	Load (lbf)	Pressure (psi)	Radius (in)
1	0	0	9000	120	4.886

Location No: 1
X-Position (in): .000   Y-Position (in): .000

Normal Stresses

Z-Position (in)	Layer *	Sxx (psi)	Syy (psi)	Szz (psi)	Syz (psi)	Sxz (psi)
0.1	1	-118.25	-118.25	-120	0	(
0.5	1	-103.94	-103.94	-119.84	0	(
1.0	1	-86.95	-86.95	-118.91	0	(
1.5	1	-71.56	-71.56	-116.71	0	(
2.5	1	-46.89	-46.89	-107.98	0	(

Western Kentucky Parkway
Maximum Shear Stress at 104°F
Comparing Laboratory with Calculated Stresses at Various Depths

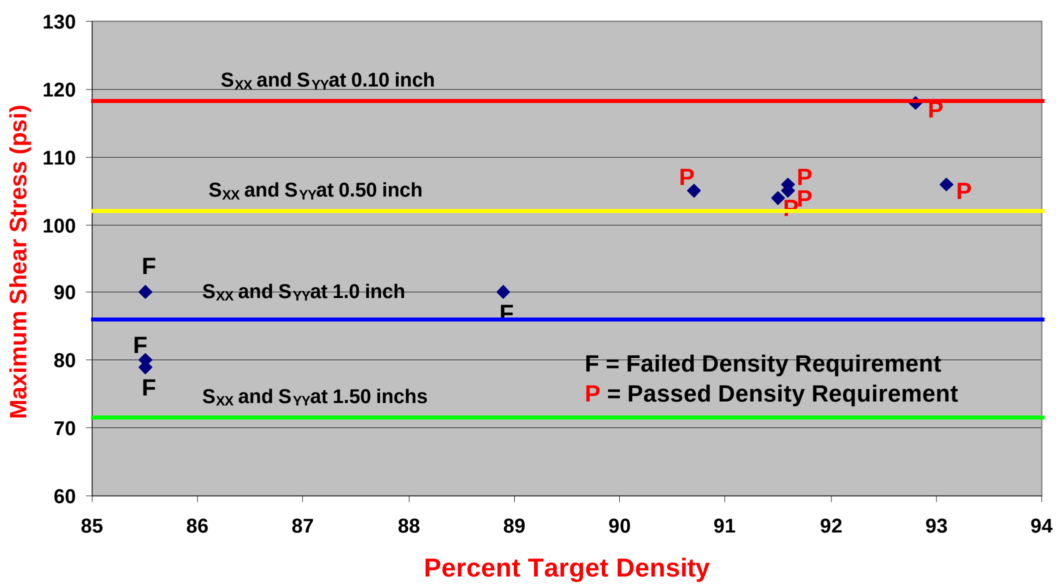

Figure 6. Comparing Laboratory Stresses with Calculated Horizontal Stresses.

Figure 7 compares the laboratory stresses with the calculated vertical Stresses (S_{ZZ}). Again, the vertical stresses are all greater than the shear strength obtained form the laboratory tests. This also indicates that rutting or consolidation in the wheelpath may be a problem.

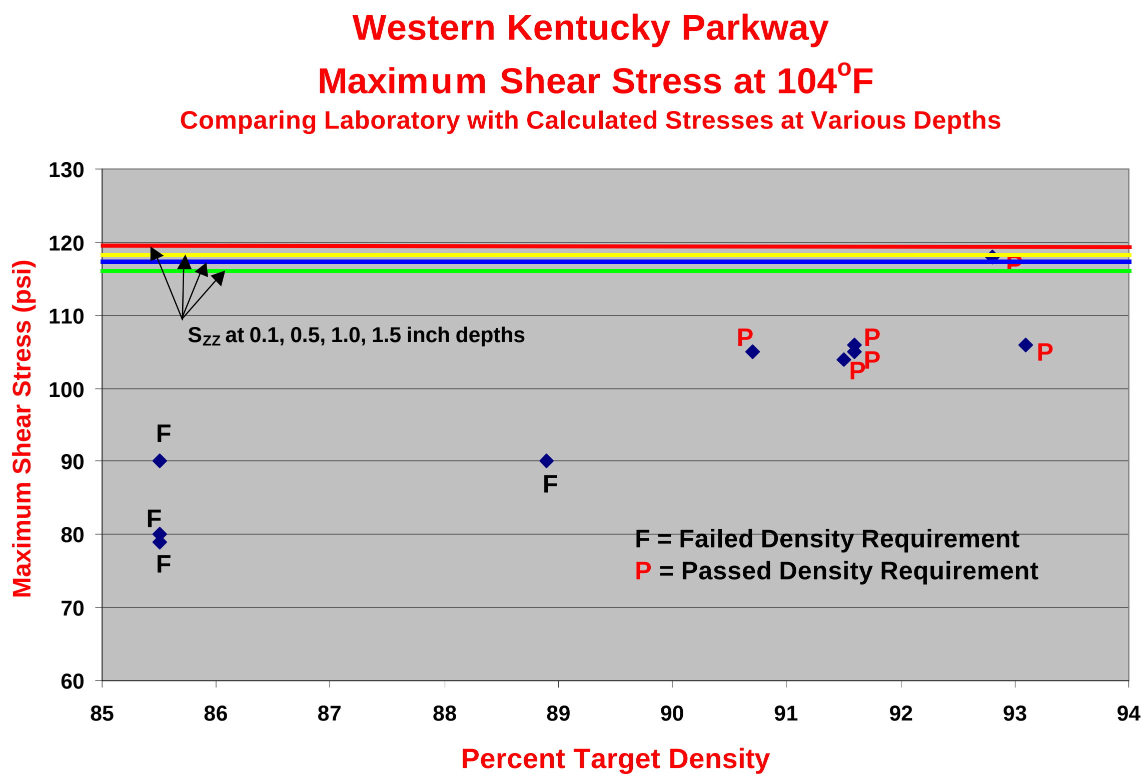

Figure 7. Comparing Laboratory Stresses with Calculated Vertical Stresses.

Conclusions

! The pavement permeability is highly dependent on the target density. The Densities that were less than the minimum of 90 percent had much higher permeability than the locations where the densities were above the minimum. Experience has shown that pavements with high permeabilities tend to have more problems with stripping and raveling. It is suspected that this pavement will have a shortened service life because of these high permeabilities.

! Nearly all (only one exception) of the laboratory shear tests had maximum shear strengths less than the stresses calculated from the layered elastic analysis. This indicates that there is a high probably that rutting will occur on this project and that an excessive amount of consolidation may occur in the wheelpaths.

! From all of the tests conducted on this project, it is expected that the pavement will have a shortened service life and poor long-term performance. How much will these deficiencies reduce the service life? The State of Kentucky has no firm numbers to answer this question; however, the State of Michigan (1) has conducted a long-term study to determine how deficiencies in density affect pavement performance. Their conclusion is that pavements with low densities (open and heavily segregated pavements) can reduce service life by as much as 50 percent.

Recommendation

In view of the data obtained and the analysis conducted in this study, and in view of the information contained in the Michigan study, it is the author’s opinion and recommendation that the best remedial action for this project is to remove and replace the “out-of-spec” material.

Reference

Wolf, Thomas F., Baladi, Gilbert Y. and Chang, Chieh-Min, *Detecting and Quantifying Segregation in Bituminous Pavements and Relating Its Effect to Condition,* Michigan State University, Department of Civil and Environmental Engineering, East Lansing, Michigan, March 2000.