COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
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June 2, 1971

H-3-15

MEMORANDUM: J. R. Harbison
State Highway Engineer
Chairman, Research Committee

SUBJECT: Tar Concrete Pavement Performance; KY 15 (Junction KY 7 to Sassafras); KYP-15; HPR - 1 (6), Part III; Experimental Construction

The report enclosed herewith relates the construction history and interim performance of an experimental pavement in which coal tar (RT-12) was substituted for asphalt cement (PAC-5) -- all other design features were basically similar to asphaltic concrete paving projects abutting each end of the experimental section. The resulting tar mixtures were in general conformity with Mixes 4T (base) and 7T (surface) of ASTM D 1753-67. Although the Marshall stability was 3000 pounds at 100°F, the tar surface course has thinned in the wheel tracks and thickened outside the wheel paths. Tar mixes have insufficient strength to withstand testing at 140°F. The greater sensitivity of the tar to summer temperatures -- together with very heavy wheel loads -- suffice to explain the greater rutting occurring in the tar surface than in the asphalt sections. Only the heavy wheel loads were unanticipated. Deflection measurements indicate that the tar concrete pavement is otherwise comparable to the two asphaltic concrete pavements abutting thereto.

Leveling of the existing surface, together with an insulating overlay of asphaltic concrete, should restore the pavement to normal service capabilities. Whereas the report indicates that 4.5 inches would be needed to restore the pavement to the original 20-year design, I would recommend a 2.5-inch overlay (plus .5-inch allowance for leveling) at this time -- thereby deferring the remaining 2 inches until a more definite need becomes evident.

Some state highway departments restrict tar concretes to base courses only; some have successfully used tar in surfaces.

Respectfully submitted,

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Research Report
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HOT-MIX COAL-TAR CONCRETE PAVEMENT
(Construction and Interim Performance)

by

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Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

June 1971

INTRODUCTION

Objectives and Scope

The principle objectives of this research were:

1. To compare the economics and performance of coal tar to asphalt cement;
2. To develop reliable coal-tar construction specifications;
3. To familiarize personnel with coal-tar construction; and
4. To implement Section 201, Subsection d and e, of the Appalachian Regional Development Act of 1965.

To accomplish these objectives, a 6.6-mile experimental section utilizing coal-tar (RT-12) concrete base and surface and 5.1-mile and 5.7-mile control sections utilizing asphalt (PAC-5) concrete base and surface were placed on relocated KY 15 in Perry, Knott, and Letcher Counties during the 1969 and 1970 construction seasons. The pavement consisted of an 11-inch DGA base, two 2½-inch Class I base courses, and a 1½-inch Class I, Type A surface course. The coal tar was supplied by the Barrett Division of Allied Chemical Corporation.

This report covers the Research Division's task of writing the special provision for the coal-tar concrete, surveillance of the construction, laboratory evaluation of the paving materials, and analysis of the comparative performance of the experimental and control sections.

Background

A research study was conducted, beginning in 1959, which involved development and evaluation of a coal-tar binder prepared from coal-tar, coal-tar oils, and powdered coal (1, 2, 3, 4). These modifications were intended to increase the softening point of the coal tar. A total of 13 sections of pavement on 12 surfacing projects over the state were selected and constructed for evaluation of the binder. These sections were constructed as a part of normal asphaltic concrete paving contracts in which the coal-based, coal-tar binder was substituted for asphalt cement in a portion of each project. Included in the experimental sections were resurfacing of asphaltic concrete and some new construction. Various laboratory and field tests were performed to support and supplement evaluation of the performance of the modified coal-tar binder. The experiments were successful in minor degree only.

Under the Appalachian Regional Development Act of 1965, P.L. 89-4, Section 201, Subsection d, states may give special preference to the use of mineral resources indigenous to the Appalachian region in construction of highways authorized under this section. With regard to research and development, Section 201 (e) of the Appalachian Regional Development Act of 1965 provides that:

> *"For the purposes of research and development in the use of coal and coal products in highway construction and maintenance, the Secretary is authorized to require each participating State, to the maximum extent possible, to use coal derivatives in the construction of not to exceed 10 per centum of the roads authorized under this Act."*

The KY 15 coal-tar surfacing project is largely a result of the Appalachian Regional Development Act.

PROJECT DESCRIPTION

The project is located on KY 15 in Eastern Kentucky's Perry, Knott, and Letcher Counties.

Located in mountainous terrain, this road is being reconstructed as a high-type, 60-mph facility utilizing two, three, and four lane sections.

Location maps are contained in APPENDIX A.

Control Section (C-1); F 102(55), APD 102(62), and APD 102(61)

The Hazard-Whitesburg Road (KY 15) from East Main Street in Hazard (Sta 0+00), extending southerly 5.65 miles to junction with KY 7, near Jeff, in Perry County (Sta 298+75).

Coal-Tar Section (TAR); APD 102(64) and APD 102(65)

The Hazard-Whitesburg Road (KY 15) from its junction with KY 7, near Jeff, in Perry County (Sta 298+75), extending southerly 6.6 miles to near Red Oak Branch (Sassafras) in Knott County (Sta 648+51.13).

Control Section (C-2); APD 102(66)

The Hazard-Whitesburg Road (KY 15) from Red Fox, in Knott County (Sta 400+00), extending southerly 5.09 miles to Isom in Letcher County (Sta 668+78).

Note: There is a 6.3-mile section of KY 15 in Knott County, between the experimental (TAR) and control section (C-2), which is being constructed by the Corp of Engineers (Carr Creek Reservoir Area).

DESIGN OF PAVEMENT STRUCTURES

Inasmuch as performance comparisons between the coal-tar binder and asphalt were sought in this instance, the pavement structures were purposefully made equal in all other respects. The design CBR's were 9 throughout; the EWL's were estimated at 40-80 million. Total thickness required was 17.5 inches (11 inches DGA base and 6.5 inches bituminous concrete).

Coal-tar binder was substituted for asphalt cement on the basis of equal volume (Specific Gravity of Tar, 1.253 @ 77°F).

CONSTRUCTION

The coal-tar section involved two projects. Project APD 102(64) began near Jeff in Perry County (Sta 298+75) and extended southerly to near Scuddy in Perry County (Sta 471+50). Bizzack Brothers Construction Corporation, Frankfort, received the contract awarded July 2, 1968. Project APD 102(65) began near Scuddy (Sta 471+50) and extended southerly to near Red Oak Branch in Knott County (Sta 648+51.13). Greer Brothers and Young Incorporated, London, received the contract, which was awarded July 24, 1968.

Summary construction data for the three projects follow:

	Section C-1	Section TAR	Section C-2
Surfacing Contractor	Adams Const. Corp. Hazard	Adams Const. Corp. Hazard	Adams Const. Corp. Hazard
Date Base Paving Began	May 5, 1969	Aug 12, 1969	July 27, 1970
Date Surface Paving Completed	Sept 6, 1969	Nov 17, 1969	Oct 15, 1970
Date Traffic Began Using Section	Some local traffic during paving; opened officially Sept 9, 1969.	Is not officially opened to thru traffic; local traffic during and since paving.	Opened to traffic officially Oct 19, 1970

On August 12, 1969, Adams Construction Company, Hazard, began laying the first tar-concrete base course on contract APD 102-64. Laying temperature at paving was 205°F. The 3.2 miles were completed by October 4, 1969.

During this period, the newly laid pavement emitted white-to-light-gray, odorous vapors. This evaporation was concentrated in the area of the paver and the first or breakdown roller, and continued for approximately 20 minutes. The problem abated considerably on cool days. Dryness and irritation of skin of workmen involved in paving resulted on warmer days.

At the request of the resident engineer, a short test was made to determine the effect of lower aggregate temperatures on the tar-concrete mix and the intensity of vapor emission. This test took place on September 16, 1969. The aggregate temperature was lowered to give the tar-concrete mixture a temperature in the vicinity of 200°F. Immediately after one of the trucks had dumped into the paver and the paver started, the mix temperature was taken. The mat temperature was 180°F. The lowered temperature affected the workability of the mixture making it stiff and more open when laid. Therefore, the temperature change adversely affected the mixture. The plant temperatures were restored to normal after 17 loads were used.

The second 3.2 miles of this project were started about October 14, 1969, and completed November 17, 1969. The cooler season resulted in less discomfort to workmen. Views of the construction operations are shown in Figures 1 and 2.

PERFORMANCE SURVEYS

Performance surveys were made in July 1970, October 1970, March 1971, and April 1971. These surveys consisted primarily of deflection, rutting, density, and core measurements.

July 1970

Around June 24, 1970, the Division of Research was requested to investigate surface cracking and rutting in the tar-concrete surface. The distress was particularly noticeable on superelevated curves. The first evidence of movement or cracks (noted by District personnel) occurred within 18 inches of the outer edge of the curve. On June 29, a general survey was made. On July 7, cores were taken from the areas of cracking and rutting. On July 10, measuring tacks were driven into

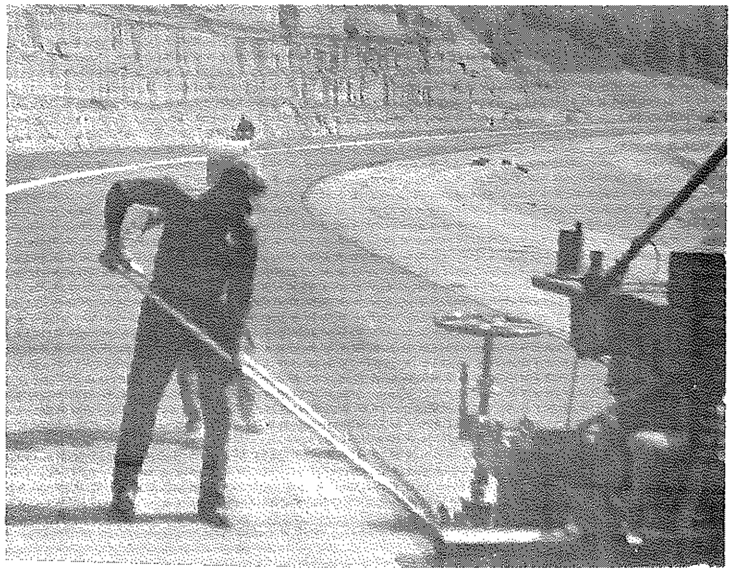


Figure 1. Laying Tar-Concrete Surface, August 1969.

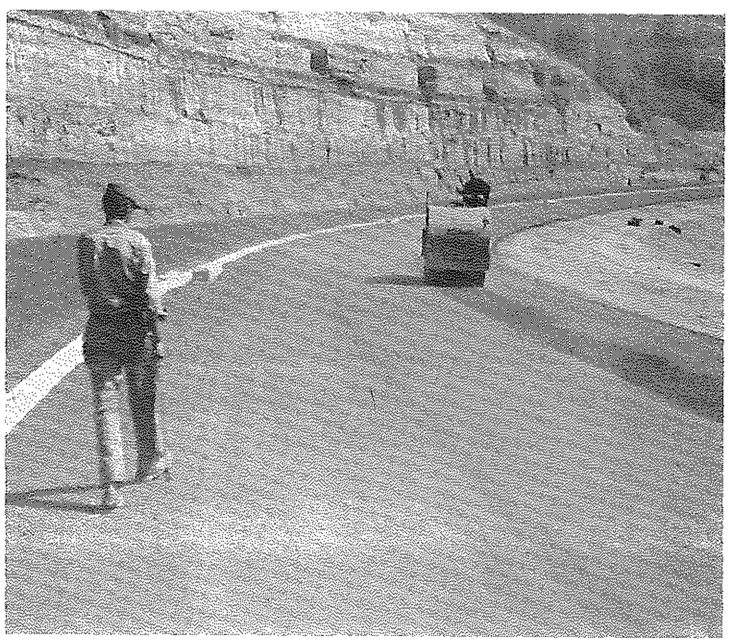


Figure 2. Rolling Tar-Concrete Surface, August 1969.

the surface to enable the determination of possible transverse movements of the surface layer. On July 15 and 16, deflection measurements with Benkleman beams and density-moisture measurements with the Seaman nuclear density meter were made.

The worst rutting and cracking (Figure 3) was observed on a superelevated curve located between Stations 630+00 and 645+00 in Knott County, about 300 feet north of end of project. The superelevation at this point is 1.944 feet in a 24-foot width. Three cores were taken in a longitudinal direction at the outer edge of the pavement where cracking had occurred. Five cores were taken on a transverse line: one near the centerline, one in the inner wheel track, one between wheel tracks, one in the outer wheel track and one outside the outer wheel track near the inner (sic) edge of the curve (Figure 4). The transverse pattern provided a cross-sectional view of relative pavement depth (Figure 5). The cracks are shown in Figure 6. Core measurements are summarized in Table 1. There was an average of 152.6 pcf density, 2.446 specific gravity, and 6.669 inches thickness. Considering the design values of 151.5 pcf density, 2.493 maximum specific gravity, and 6.5 inches total thickness, there had been relatively little variation or change in the volume of the material since construction.

The only item which indicates a sizeable variation is the depths of cores. The rutting within the bituminous-bound layer appeared to be one inch. Total rutting was on the order of 1.5 inches. The 0.5-inch differential is considered to be attributable to rutting of the DGA base and (or) subgrade. Measurement of the 2- to 2.5-inch RT, Class I base courses did not indicate appreciable changes in thickness. It appears that the surface course between wheel tracks and at the inner edge of superelevated curves increased thickness -- indicating lateral movement.

The deflection measurements were taken using two beams simultaneously (one in each wheel track between the dual tires). The three loading conditions were as follows:

1. Kentucky Department of Highways dump truck -- dual wheels, single rear axle, 18,000-pound load.
2. Ford dump truck -- dual wheels, tandem axle, 55,000-pound total load on rear axles, 52 inches between axles, 21-foot bed length.
3. Mack dump truck - dual wheels, tandem axle, 60,000-pound total load on rear axles, 56 to 60 inches between axles, 23-foot bed length.

The deflection measurements using the Ford Dump were taken in the vicinity of Scuddy on the tar section; those using the Mack Dump were taken in the vicinity of Christopher on the asphalt cement (C-1) section. Density measurements with a nuclear gage were taken at these same sites.

The highest temperature of the pavement surfaces during the deflection testing was 112°F; the ambient air temperature was 82°F. The day before deflection measurements were taken, a surface temperature of 127°F was recorded in a tar area which was then found to be soft on the surface and unstable.

The deflections and densities are shown in Table 2. The Kentucky Department of Highways Dump Truck (18,000-pound rear axleload) was used as a standard for comparison on both types of bituminous pavements. The deflections of the tar section do not appear to be significantly different from those obtained on the asphalt sections.

The nuclear density results show that the densities at the RT-deflection test sites compare favorably with the core test data – indicating a uniformity between these physical properties of the material.

Based on observations in the field and analysis of field samples and data, the following summary

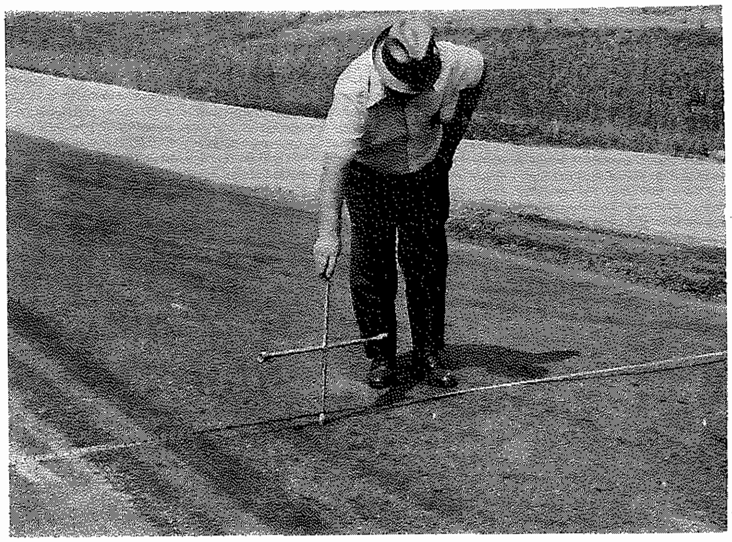


Figure 3. Wheel-track Rutting, July 1970.

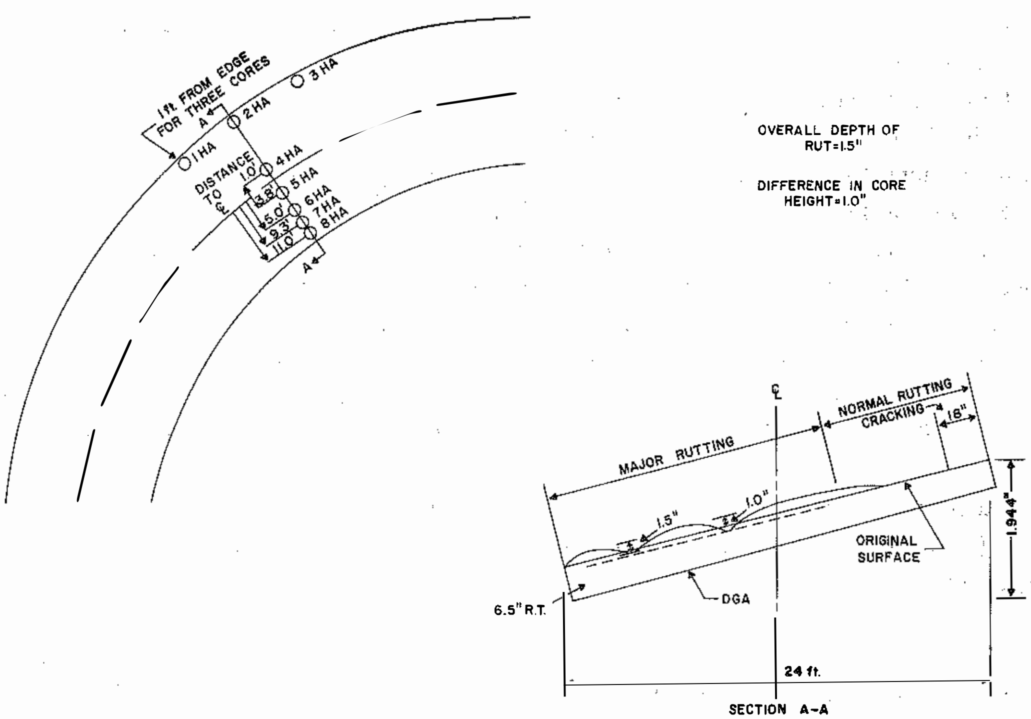


Figure 4. Core Location and Section Sketch, KY 15, Knott County, Sta 644+00.

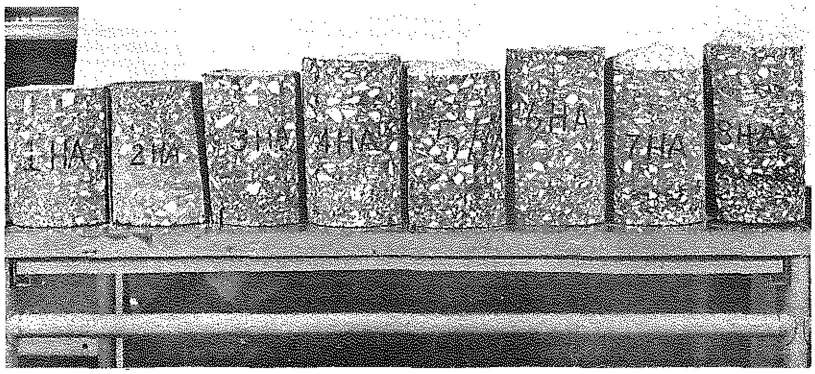


Figure 5. Cores taken July 1970 (Cores are upside down).

Figure 6. Surface View of Cracks in Cores taken July 1970.

TABLE 1. CORE DATA, KY 15, KNOTT COUNTY
STA 644+00 (JULY 1970)

IDENTIFICATION	LOCATION	CORE LENGTH (inches)	SURFACE THICKNESS (inches)	SPECIFIC GRAVITY	UNIT WEIGHT (pcf)
1HA	Outer Edge of Curve	5.9	1.2	2.423	151.2
2HA	Outer Edge of Curve	6.0	1.2	2.445	152.6
3HA	Outer Edge of Curve	6.5	1.5	2.451	152.9
4HA	Near Centerline	7.1	2.1	2.444	152.5
5HA	Inner Wheel Track	6.5	1.5	2.448	152.8
6HA	Between Wheel Tracks	7.4	2.0	2.453	153.1
7HA	Outer Wheel Track	6.6	1.6	2.449	152.8
8HA	Inner Edge of Curve	7.5	2.5	2.456	153.2
	Averages	6.7	1.7	2.446	152.6
	Design Values	6.5	1.5	2.493 max	151.5

TABLE 2. DEFLECTION AND DENSITY DATA, KY 15
PERRY COUNTY, STA 644+00 (JULY 1970)

TYPE OF TRUCK AND LOCATION	TYPE OF PAVEMENT	MEASURED DEFLECTION (inches)		PAVEMENT SURFACE TEMPERATURE (°F)
		INNER WHEEL TRACK	OUTER WHEEL TRACK	
Highway Department Dump Truck (18-kip, single rear axle)				
At Scuddy	RT-12	0.010	0.030	97
At Christopher	PAC-5	0.022	0.031	112
Ford Dump Truck (55-kip, double rear axle)				
At Scuddy	RT-12	0.026	0.047	102
Mack Dump Truck (60-kip, double rear axle)				
At Christopher	PAC-5	0.026	0.041	112

Notes: Air Temperature 82°F
Nuclear Unit Weights:
Tar Concrete 152.5, 152.5, 152.5 pcf
Asphaltic Concrete 144.5, 150.5 pcf

was submitted as of July 1970:

1. The tar surface course appears to be moving to the inside edge of superelevated curves. This movement is caused by heavy loads and high temperatures. The high temperature causes the tar to soften. The high axleloads, being in excess of design loads, compound the extent of movement due to temperature. Surface temperatures of about 150°F could be anticipated during the summer.

2. The design parameters were Traffic Curve VIII (60 x 10^6, 5,000-pound EWL's or 2 x 10^6, 18,000-pound EAL's) and CBR 9, resulting in a total pavement thickness of 17.5 inches. By extrapolating, axleloads of 55,000 and 60,000 pounds compound into a Traffic Curve XVI or 512 x 10^6 EAL's (16.4 x 10^9 EWL's) in 20 years. Loading was estimated from an ADT of 2,000 and about 10 percent trucks. Design for the axleloads discussed above would require a total pavement thickness of 39 inches at a 33% bituminous concrete thickness to total thickness ratio.

A surface treatment which would reflect heat might help prevent softening of the existing RT surface. This should minimize pavement movement (creep) under loading. Analysis also indicates that an additional 12 inches of bituminous concrete would be required to support, for a 20-year design period, the traffic loads which have actually been observed to be using the highway. This would result in a pavement structure of approximately 65 percent bound thickness and 35 percent unbound. The additional 12 inches also assumes that the existing pavement system can be recognized as equal to new pavement and thus having its full structural (load-carrying) capabilities.

October 1970

A detailed condition survey was performed on the control section (C-1) and the experimental tar section on October 21. Major items investigated were rut depths, cracking, and shoulder failures. Table 3 contains wheel-track rutting data, and Figure 7 contains a sketch noting the defects and their locations as of that date.

Three tacks which were driven into the tar surface at Milepoint 12.21, on July 10, 1970, were measured. A tack at the centerline had moved down the superelevated curve about one foot. A tack at the inside edge of the curve had moved about 18 inches longitudinally.

March 1971

A cursory inspection of the tar concrete surface was made on March 5. Figures 8 and 9 depict areas of severe rutting. The rutting, as of this date, existed throughout practically the entire length. The rutting had a very noticeable influence on the driveability of an automobile.

No breakup of the surface was noted. Cracking occurred only in conjunction with severe rutting. It is a type of longitudinal cracking -- parallel to the rutting and generally occurs on the side or slope of the ruts. Only one small patch was noted -- this being over a drainage structure.

Two series of rutting measurements were taken. The first series was taken near the southern end of the project, near the site where cores had been previously taken. This area probably represented the most severe rutting. Ruts 2.5 inches deep were measured. Ruts between 1 and 2 inches deep were more prevalent. The second series of rutting measurements was taken at a patched area, near Happy. The ruts were not as deep there.

April 1971

On April 15 very detailed and inclusive wheel-track rutting measurements were taken on the

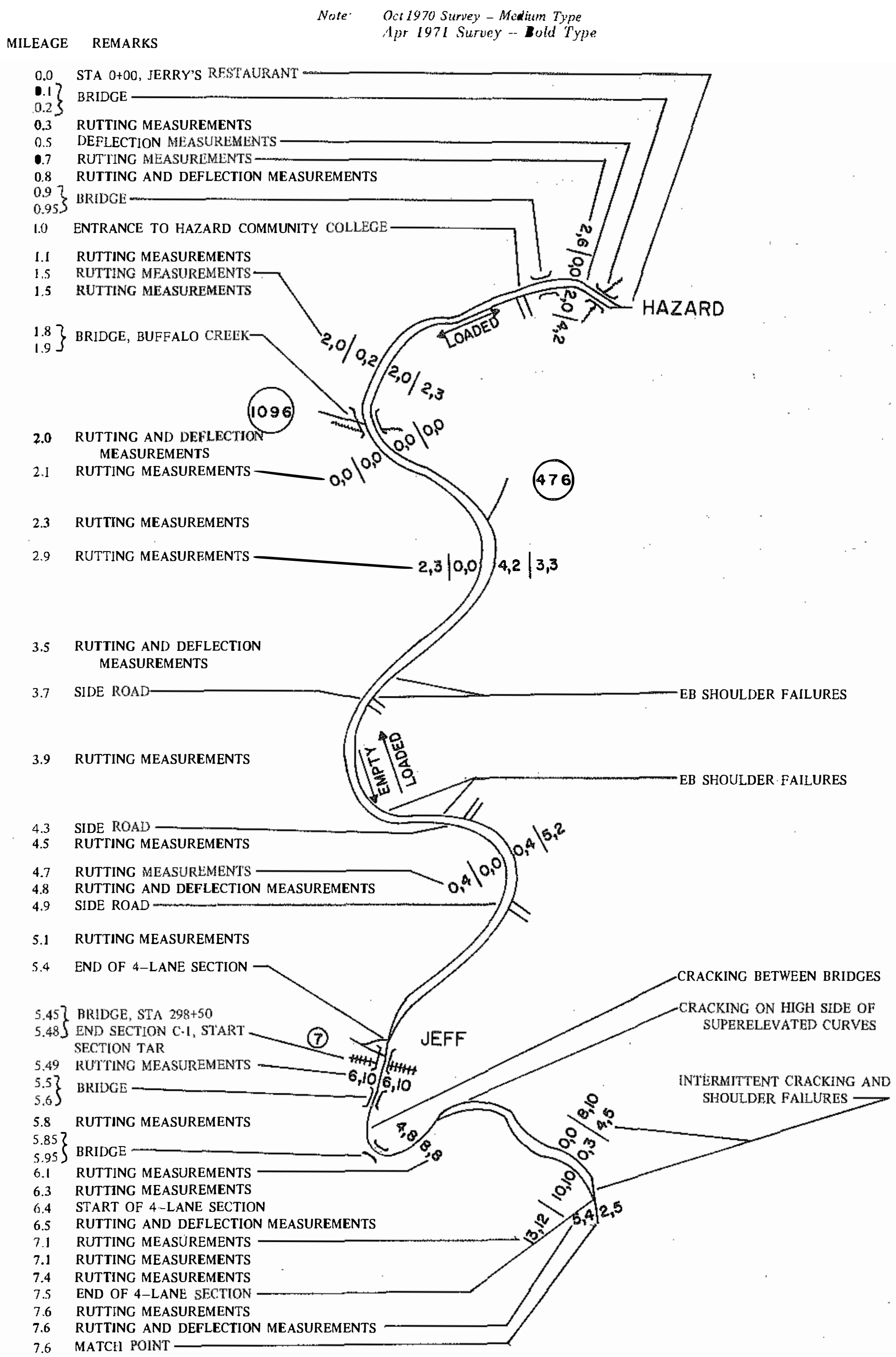


Figure 7. Sketch of Pavement Defects on Sections C-1 and TAR – Hazard to Sassafras.

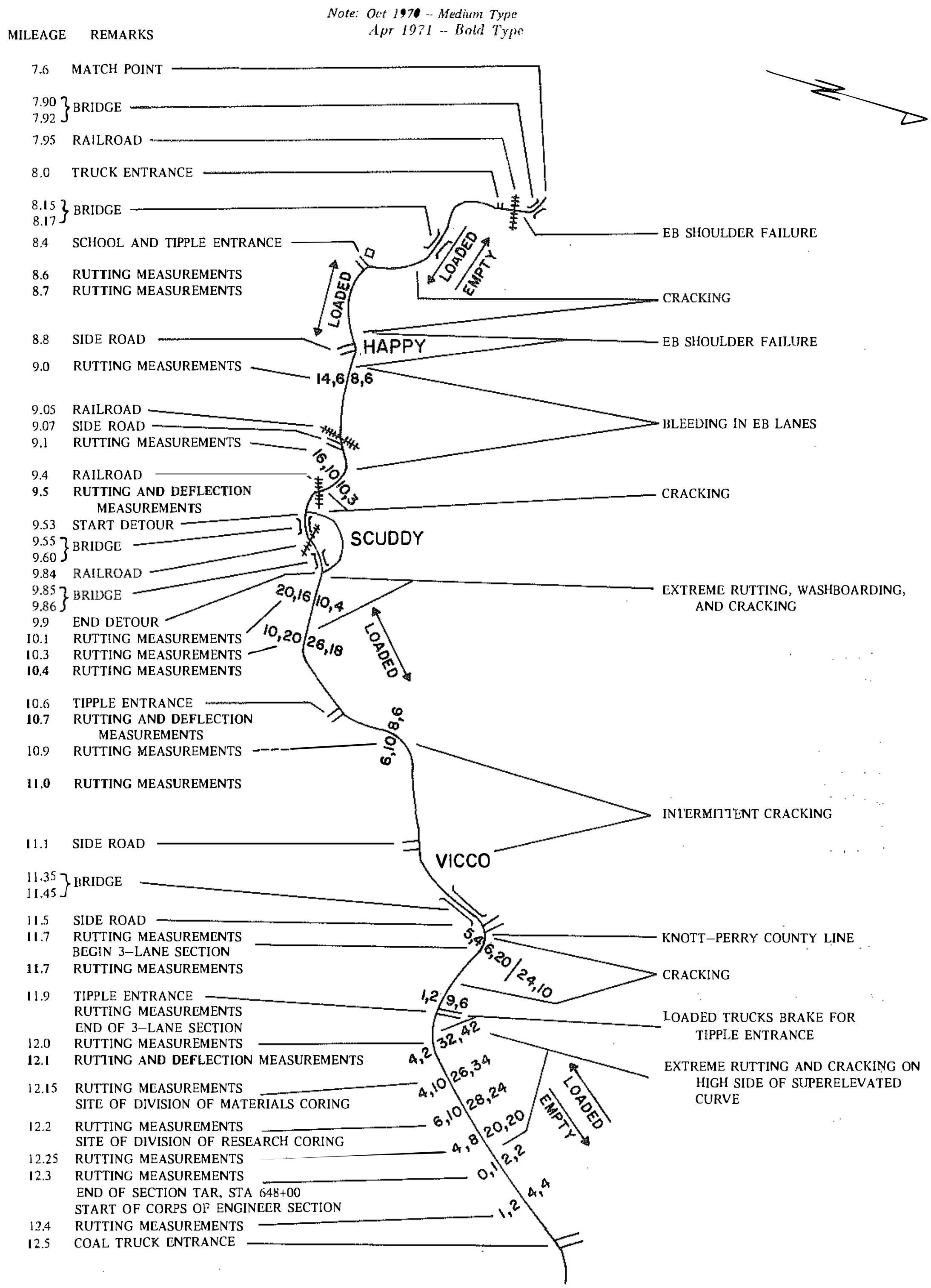


Figure 7. Sketch of Pavement Defects on Sections C-1 and TAR -- Hazard to Sassafras.

TABLE 3. RUT DEPTHS ON KY 15, HAZARD TO SASSAFRAS

NO.	TERMINI	LANE	ASPHALTIC CONCRETE (inches)	TAR CONCRETE (inches)	REMARKS
1	Hazard to KY 1096	EB	0.156		Heavy Loads
		WB	0.171		Heavy Loads
		Average	0.164		
2	KY 1096 to KY 476	EB	0*		Normal Loads
		WB	0*		Normal Loads
		Average	0*		
3	KY 476 to KY 7	EB	0.141		Normal Loads
		WB	0.203		Heavy Loads
		Average	0.172		
	Hazard to KY 7	Average EB	0.148		
		Average WB	0.187		
		Average	0.168		
4	KY 7 to Happy	EB		0.552	Heavy Loads
		WB		0.396	Normal Loads
		Average		0.474	
5	Happy to 1.25 miles east of Scuddy	EB		0.960	Heavy Loads
		WB		0.740	Heavy Loads
		Average		0.849	
6	1.25 miles east of Scuddy to tipple entrance 0.28 miles east of Knott-Perry County line	EB		0.292	Normal Loads
		WB		1.013	Heavy Loads
		Average		0.704	
7	Tipple entrance to end of tar concrete section	EB		0.375	Normal Loads
		WB		1.583	Heavy Loads
		Average		0.893	
8	Corps of Engineers section, end of tar section to 0.15 miles east	EB	0.063		Normal Loads
		WB	0.188		Heavy Loads
		Average	0.125		
9	Average of all sections	EB	0.120	0.545	
		WB	0.188	0.742**	
		Average	0.154	0.639**	

* These measurements were not included in the averages since the section was very short and the heavy truck traffic did not use the section.

** Two ruts in WB lanes east of a tipple entrance measured 2 and 2 5/8 inches. These two measurements were eliminated from this analysis because the action of applied truck brakes produced approximately twice the rut depth where normal running speeds occurred.

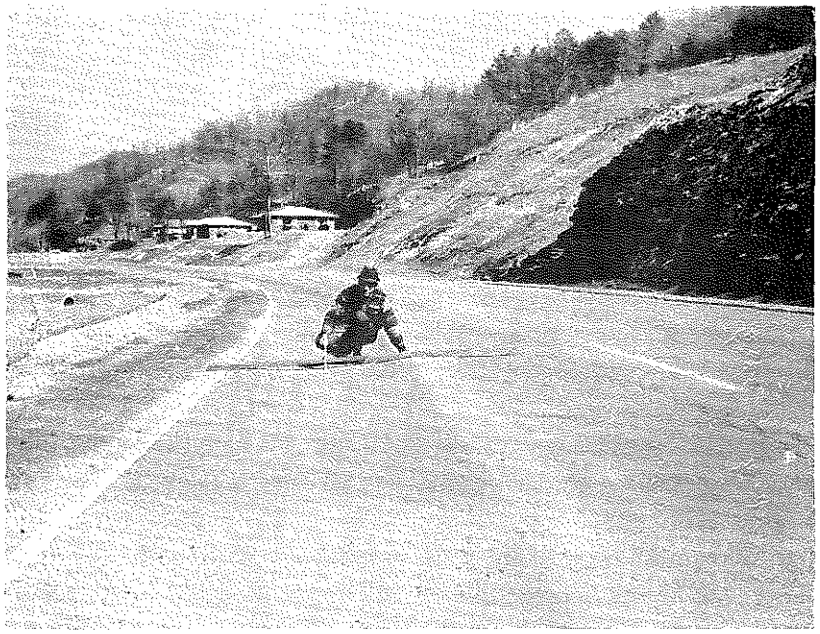


Figure 8. Area of Severe Rutting near South End of Project, March 1971 (Also note cracks).

Figure 9. Close-up of Figure 8; Note 2.5-inch Rut Depth.

experimental (tar) and control sections (See Figure 10).

The location of the rutting measurements were randomly selected. An average of two per mile were taken. Measurements were taken in each wheel track. Each location was marked for future reference with a nail and bottle cap at the outside edge of the southbound lane. A daub of orange paint was also applied around the bottle cap and a marked stake was placed on the shoulder.

Summary data are contained in Table 4. Passing lane measurements are included in the "outer" lane data. Two-lane sections were noted as having outer lanes only. Note that the average rut depth on the tar section was approximately three times that of control sections. Table 5 contains data for each test location.

Deflection measurements using the Benkleman beam were taken on April 20 and 21. The measurements were obtained for comparison with previous readings taken during the July 1970 survey. Results are given in Table 6.

The deflections were averaged between inside and outside wheel tracks and by type of bituminous concrete. The asphalt concrete average reading was 0.020 inch. The coal tar average reading was 0.013 inch. The coal tar average is less than the asphalt section due to the temperature differentials. The coolness of the pavement at the time of coal-tar deflection readings, which caused a stiffening effect inherent with this type pavement material, is considered the reason for the lesser readings. The outer wheel track readings in Table 6 are in the magnitude of 50 percent of the readings taken during the 1970 survey (Table 2), which were taken at higher temperatures.

STRUCTURAL OVERLAY CALCULATIONS

Structural overlay calculations for the tar concrete section were made in October 1970 by the Division of Research. The calculations were based on: 1) relative damage as evidenced from rutting measurements taken during October 1970, 2) deflection measurements taken during July 1970 on the tar concrete (TAR) section and the abutting asphaltic concrete (C-1) control section, and 3) observed loading. Several estimates were offered; the criterion employed is defined in the following discussion and analysis.

Failure criteria (assumed) were: 1) ¼ - inch rut depth and/or 2) the design fatigue life of 2×10^6 equivalent 18,000-pound axleload (60 million EWL's).

The observed spacing between rear axles was 52 inches or more; therefore, the combined or dual load would be 36,000 pounds. Using the severity concept that each 2,000-pound increment per single axle (4,000 per dual axles) increases the damage according to the load-damage factor equation,

$$F = a\,(1.25)^{P - 18},$$

where P = axleload in kips and a = 1.0, produces the following table:

DUAL AXLELOAD (POUNDS)	SINGLE AXLELOAD (POUNDS)	SEVERITY FACTOR
36,000	18,000	1.0000
40,000	20,000	1.5625

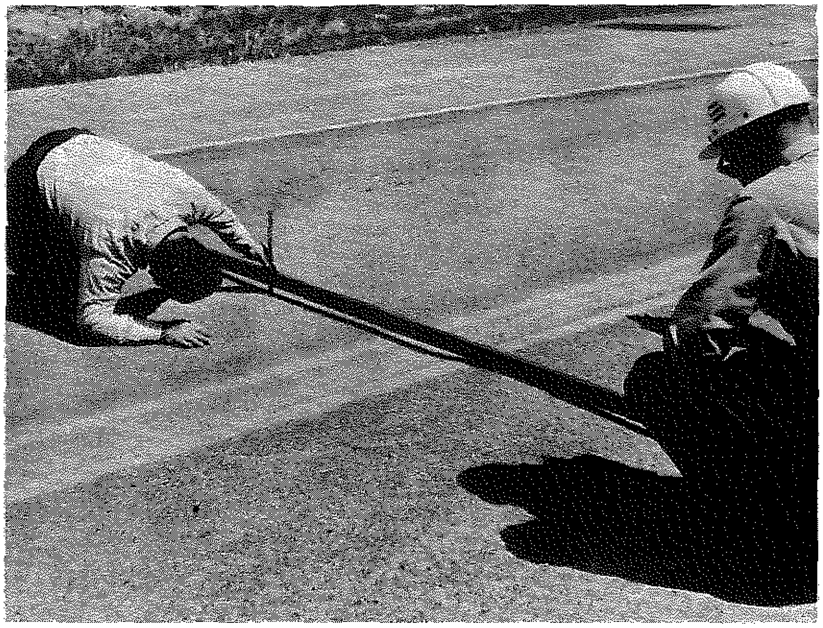


Figure 10. Procedure Used to Obtain Wheel-Track Rutting Measurements, April 1971.

TABLE 4. SUMMARY OF WHEEL-TRACK RUTTING DATA

SECTION	RUTTING DEPTHS (inches)	
	OUTSIDE OR PASSING LANES*	INSIDE LANES*
C-1	0.22	0.09
TAR	0.57	0.15
C-2	0.14	0.10

*Average for both wheel tracks in both directions.

Note: Inside lanes occur only on four-lane or passing sections.

TABLE 5. SUMMARY OF RUTTING MEASUREMENTS, APRIL 1971

SECTION	COUNTY	LOCATION	RUTTING MEASUREMENTS (1/16's of an inch)							
			NORTHBOUND LANES				SOUTHBOUND LANES			
			OUTSIDE LANE		INSIDE LANE		INSIDE LANE		OUTSIDE LANE	
			OUTER TRACK	INNER TRACK	OUTER TRACK	INNER TRACK	INNER TRACK	OUTER TRACK	INNER TRACK	OUTER TRACK
C-1	Perry	(Miles from beginning of project at Hazard) 0.3	1	1	–	–	0	1	4	8
		0.9	2	3	2	0	1	3	1	4
		1.1	3	1	1	0	0	0	4	1
		1.5	3	3	1	0	0	0	4	2
		2.0	5	8	1	3	1	0	3	2
		2.3	1	2	3	0	0	0	10	1
		3.5	1	4	0	4	1	0	8	0
		3.9	4	4	3	1	3	2	4	3
		4.5	3	3	3	10	2	4	4	5
		4.8	3	8	0	6	1	0	4	2
		5.1	3	7	2	0	3	0	8	3
		Averages	2.64	4.00	1.60	2.40	1.09	0.91	4.91	2.82
TAR	Perry-Knott	(Miles from beginning of project at Jeff) 0.3	5	6	–	–	–	–	6	6
		0.8	8	8	–	–	–	–	8	12
		0.9	5	4	–	–	–	–	6	11
		1.6	7	7	3	3	3	4	6	9
		1.9	8	5	1	3	2	3	11	15
		2.1	4	5	–	–	–	–	12	8
		3.1	4	4	–	–	–	–	9	7
		3.2	6	5	–	–	–	–	5	6
		4.0	9	18	–	–	–	–	14	7
		4.9	22	18	–	–	–	–	12	8
		5.2	5	7	–	–	–	–	8	7
		5.5	16	14	–	–	–	–	10	9
		6.2	3	2	0	1	–	–	8	6
		6.5	32	24	–	–	–	–	9	8
		Averages	9.57	9.07	1.33	2.33	2.50	3.50	8.86	8.50
C-2	Knott-Letcher	(Miles from beginning of project at Red Fox) 0.4	1	7	0	3	3	1	8	0
		1.1	0	0	0	6	2	0	3	2
		1.5	3	4	–	–	0	0	1	3
		1.7	0	5	–	–	2	1	0	1
		2.1	3	3	–	–	1	1	0	0
		2.4	0	5	0	0	5	1	3	3
		3.0	2	1	4	0	–	–	0	2
		3.4	0	3	2	0	–	–	2	4
		4.2	1	6	2	3	3	0	0	1
		4.6	3	6	–	–	–	–	3	1
		Averages	1.30	4.00	1.33	2.00	2.29	0.57	2.00	1.70

TABLE 6. DEFLECTION DATA, APRIL 1971

LOCATION		TYPE OF PAVEMENT	MEASURED DEFLECTIONS (inches)		PAVEMENT SURFACE TEMPERATURE (°F)
			INNER WHEEL TRACK	OUTER WHEEL TRACK	
(Miles south of Jerry's at Hazard)	0.0	PAC-5	---	---	---
	0.9		0.012	0.022	101
	2.0		0.033	0.022	108
	3.5		0.017	0.030	110
	4.8		---	0.060	113
(Miles south of Jeff -- Perry County)	0.0	RT-12	---	---	---
	0.9		---	---	114
	2.1		---	---	112
	3.2		0.012	0.026	110
	4.0		0.012	0.018	62
	5.2		0.007	0.012	63
	6.6		0.008	0.008	62
(Miles south of Red Fox-Knott County)	0.0	PAC-5	---	---	---
	1.1		0.011	0.018	68
	1.7		0.010	0.020	67
	3.0		0.017	0.024	65
	4.2		---	---	---

Notes: Measurements made with a Highway Department dump truck:

Front axle - 5,650 pounds
Single rear axle - 18,000 pounds

44,000	22,000	2.4414
48,000	24,000	3.8147
52,000	26,000	5.9605
56,000	28,000	9.3132
60,000	30,000	14.5519

Therefore, each 60,000-pound dual axleload creates the same accumulative damage as 29.1 basic loads. Trucks having gross weights of 80,000 pounds carrying 60,000 pounds on the rear axles, carry 20,000 pounds on the front axles on only two tires. This implies that more damage may result from the front axle than from the dual axles. For this analysis, the front axle was given a 30,000-pound severity factor.

Since the asphaltic concrete section (C - 1) had been open to traffic for over a year, the equivalent dual axleloads that had passed over the pavement were

$$365 \text{ days} \times 150 \text{ trucks/day} \times 14.5519 \text{ EAL/truck} \times 3 \text{ axles/truck} = 2.39 \times 10^6 \text{ EAL's.}$$

This substantially exceeds the design EAL level.

The asphaltic concrete pavement was designed for a CBR 9 subgrade and 2 x 10^6 equivalent 18,000-pound axleloads. The traffic forecast (based on 7 percent compounded annual traffic increase) at the time of design was:

YEAR	ADT	ONE-DIRECTIONAL ADT
1965	1,930	965
1970	2,707	1,354
1990	10,480	5,240

A normal traffic stream would consist of 10 percent trucks, or 135 trucks per day in 1970 in one direction. Therefore, the truck traffic alone exceeded what would have been the expected normal truck traffic. Using 135 trucks per day in one direction, the EAL for one year would be:

$$135 \text{ trucks/day} \times 365 \text{ days} \times 14.5519 \text{ EAL/trucks} \times 3 \text{ axles/truck} = 2.15 \times 10^6 \text{ EAL's.}$$

This still exceeds the design level of 2,000,000 EAL.

The original concept was to use the same thickness design for both the asphaltic concrete and the tar concrete projects; the structural behavior and performance would be evaluated. The same structure was used on the Corps of Engineers project.

In order to use the AASHO design procedure to calculate an overlay for KY 15 from Hazard to Sassafras, appropriate coefficients for tar concrete had to be resolved. Possible ways of determining the relative strength of tar concrete to asphaltic concrete was to compare measured rut depths and deflection test results. A summary of measured rut depths is shown in Table 3. Normal truck loads were noted in the eastbound lanes from KY 476 to KY 7 (Section 3 in Table 3) and eastbound lanes of the Corps of Engineers section (Section 8 in Table 3). The arithmetic average of the rut depths was 0.102 inches. The arithmetic average of all rut depths for the tar sections having normal truck loads (Westbound, Section 4, Eastbound, Sections 6 and 7) was 0.354 inches. Therefore, comparative structural worth under similar normal loadings would indicate the asphaltic concrete was approximately 3.5 times superior to tar concrete. The ratio of the average rut depth of tar concrete to asphaltic concrete was

$$\text{Tar Rut Depth} / \text{Asphalt Rut Depth} = 0.639 / 0.154 = 4.15.$$

The randomized rut-depth survey of April 1971 yielded a ratio of approximately 3. Inasmuch as this ratio largely confirmed the October 1970 ratio, no revisions were considered necessary in the overlay calculations.

An asphaltic concrete overlay would provide a temperature-insulation layer and thereby reduce the temperature level in the tar concrete - resulting in greater stiffness of the tar concrete. For this reason, a reduction in the factor of 3.5 to 3.0 is justifiable. Appropriate coefficients for flexible pavements using the AASHO design procedure (Table 7) were given by the Bureau of Public Roads (now FHWA) in 1967 for use in determining the overlay thickness requirements for upgrading the existing interstate pavements to a 20-year design. This table was used to determine the appropriate material coefficients for the analysis reported herein.

In the AASHO design method, a_1 and a_2 are coefficients for the bound layer and the crushed stone base, respectively; and a_f is the constant for the subgrade layer. The "NOTE" on Table 7 states that these respective coefficients should be no greater than 0.6 and 0.7 of their original values. The adjusted coefficients are listed below:

COEFFICIENT	NEW PAVEMENTS	OLD PAVEMENTS
a_1	0.44	0.24*
a_2	0.14	0.10
a_f	1.5	1.5

The a_1 coefficient for the existing tar surface was adjusted in proportion to rut depths:

$$a_1 = 1/3\ (0.30) = 0.10^{**}.$$

The above coefficients were used to calculate the required $\overline{SN}$ values by the following equation:

$$\overline{SN} = a_1 D_1 + a_2 D_2 + a_f$$

where D_1 = bound layer thickness in inches and
D_2 = crushed stone layer thickness in inches.

**This value was judiciously readjusted to 0.30.*

***When overlaid and insulated from prevailing surface temperatures, the tar concrete might be valued higher than this; 0.20 was used for estimating overlay requirements.*

TABLE 7. COEFFICIENTS FOR FLEXIBLE AND COMPOSITE PAVEMENTS

PAVEMENT COMPONENTS	OTHER REQUIREMENTS		COEFFICIENTS		
			a_1	a_2	a_3
New Surface					
Road Mix (low stability)	Marshall stability	500-1,000	0.20	--	--
Plant mix (high stability)	Marshall stability	2,000	1/0.44	--	--
Sand asphalt	Marshall stability	1,000-1,200	0.40	--	--
Old Surface					
Old road mix surface			0.16	--	--
Old bituminous concrete surface	Undisturbed		0.24		
Old bituminous concrete surface	Scarified and mixed with old base		0.14	--	--
Base					
Sand gravel	CBR 20-30		--	2/0.7	--
Crushed stone	CBR 105-110		--	1/0.14	--
Waterbound macadam			--	0.15-0.20	--
Lime treated			--	0.15-0.30	--
Sand asphalt			--	0.30	--
Bituminous treated coarse-graded			--	2/0.34	--
Cement treated (no soil cement)	650 psi comp. str. 7-day (4 1/2% cement		--	2/0.23	--
	400 - 650 psi		--	0.20	--
	Less than 400 psi		--	0.15	--
New portland cement concrete	Surfaced with asphalt when new		--	0.50	--
Old portland cement concrete	Resurfaced with asphalt after pavement has deteriorated		--	0.40	--
Subbase					
Sandy gravel	CBR 20-30		--	--	1/0.11
Sand or sand-clay			--	--	0.05-0.10

1/ Based on AASHO Road Test data.
2/ Estimated from AASHO Road Test data, but not to the accuracy of those factors identified by footnote 1.

NOTE: In general, it is recommended that, in computing DT for resurfaced flexible pavements, the coefficient for the former surface be no greater than 0.6 of its original value, that for the former base be no greater than 0.7 of its original value, and that for the former subbase be no greater than 0.8 of its original value.

The overlay thickness was calculated by the following equation:

$$\overline{SN} = a_1 D_1 + a_2 D_2 + a_3 D_3 + a_f$$

where a_1 = coefficient for a new bound layer,
D_1 = overlay thickness of bound material in inches,
a_2 = coefficient for old bound material,
D_2 = original bound layer thickness in inches,
a_3 = coefficient for old crushed stone base,
D_3 = original crushed stone base thickness in inches, and
a_f = constant for subgrade.

Thus, D_1, the overlay thickness, is the only unknown quantity.

Overlay designs were calculated using the above criteria for the following assumed design conditions:

1. To restore the asphaltic concrete sections to the original design EAL's (2×10^6) and assuming the traffic for the next 20 years consists of legal axleloads only:
   Overlay thickness = 3.0 inches.
2. To increase the design of the asphaltic concrete sections to carry the projected heavy loads:
   Overlay thickness = 6.5 inches.
3. To increase the design of the tar concrete sections to an original equivalent, asphaltic concrete design:
   Asphaltic concrete overlay thickness = 4.5 inches.
4. To increase the tar concrete sections to carry the projected heavy loads for the next 20 years:
   Asphaltic concrete overlay thickness = 8.0 inches.

These overlay thicknesses include a leveling course of Class I mix. The top 1.0 inch of each overlay should be a Class I, Type A surface mix design. Overlays of tar concrete are not recommended for the tar section.

It is emphasized that any overlay thickness will require a shoulder treatment of the same thickness to maintain the same geometric cross-sectional standards.

LIST OF REFERENCES

1. Hardymon, J. F., *"Experimental Paving Projects Using Curtiss-Wright's Coal-Modified, Coal-Tar Binder (Construction Phase)"* Kentucky Department of Highways, June 1960.

2. Hardymon, J. F., *"Experimental Paving Projects Using Curtiss-Wright's Coal-Modified Coal-Tar Binder (First Years Performance)"*, Kentucky Department of Highways, March 1961.

3. Drake, W. B., *"Kentucky's Bituminous Pavement Research on Modified Coal Tar"*, **Bulletin No. 56**, Engineering Experiment Station, University of Kentucky, June 1960.

4. Drake, W. B., *"Experimental Paving Projects Using Curtiss-Wright's Coal-Modified, Coal-Tar Binder"*, **Bulletin 350**, Highway Research Board, 1962.

5. Halstead, W. J., Oglio, E. R., and Olsen, R. E., *"Comparison of Properties of Coal-Modified Tar Binder, Tar and Asphalt Cement,"* **Bulletin 350**, Highway Research Board, 1962.

6. Rhodes, E. O., *"Coal-Modified Tar Binders for Bituminous Concrete Pavements"*, **Bulletin 350**, Highway Research Board, 1962.

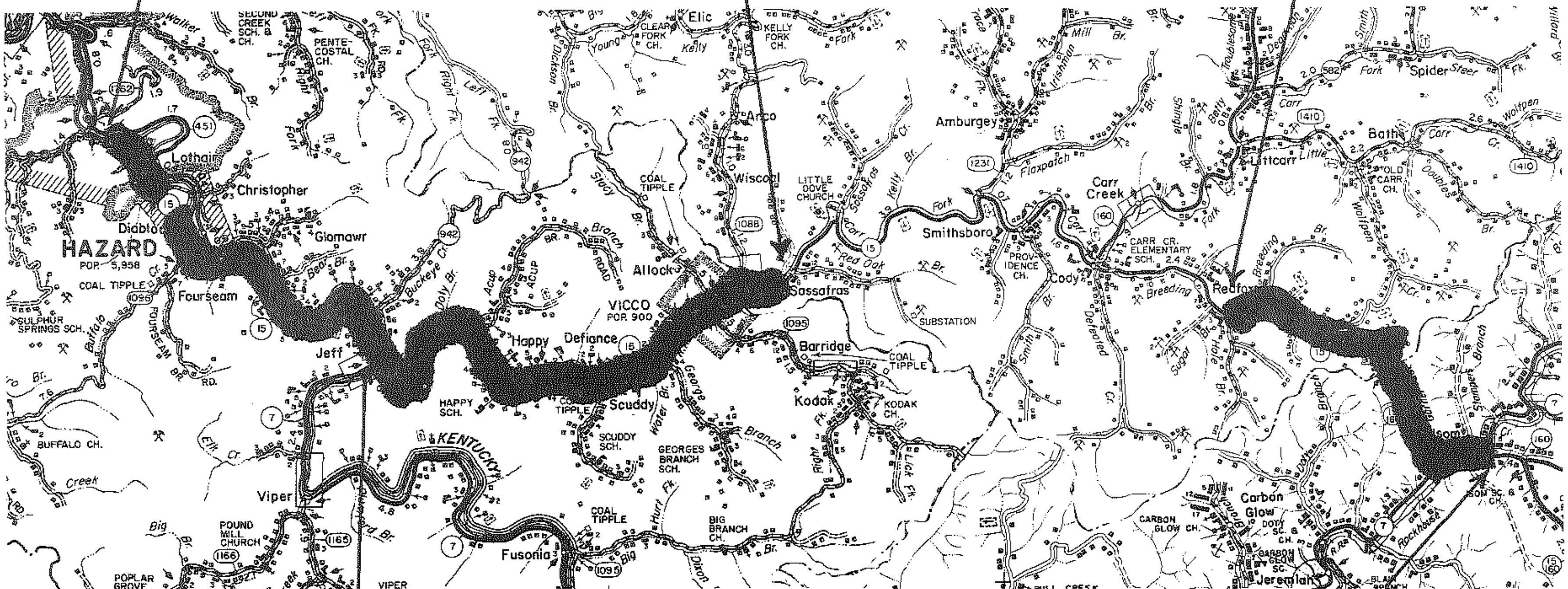
APPENDIX A

Project Maps

BEGIN CONTROL SECTION
(C-1) STA. 0+00

END COAL TAR SECTION
STA. 648+00

BEGIN CONTROL SECTION
(C-2) STA. 400+00



PERRY

KNOTT

LETCHER

END CONTROL SECTION (C-1)
BEGIN COAL TAR SECTION
STA. 298+50

END CONTROL SECTION (C-2
STA. 668+00

KY. 15 PERRY-KNOTT-LETCHER COUNTIES

APPENDIX B

Special Notes
for
Experimental
Hot-Mixed, Hot-Laid, Tar Concrete Base and Surface Courses

Special Notes
for
EXPERIMENTAL
Hot-Mixed, Hot-Laid Tar Concrete Base and Surface Courses

(A.P.D. 102 (64), Perry County, KY 15 from Junction KY 7 at Jeff to Scuddy, 3.93 miles, and A.P.D. 102 (65), Perry and Knott Counties, KY 15 from Scuddy to Red Oak Branch, 2.70 miles.)

This pavement construction work shall comply with **Sections 209** and **306** of the Standard Specification, with the following **modifications and additions**:

1. Section 306 – **RT–12** shall be used in the mixes instead of asphalt cement.
2. Article 306.3.3-A – The tar content for the base course mixture shall be between **5.5** and **6.5** per cent, and between **6.2** and **7.2** per cent for the surface course mixture (Type A), as established by the Engineer. The job-mix tolerance for the tar content shall be plus or minus **0.4** percentage point.
3. Article 306.3.3-B – The aggregates shall be at a temperature between **220°F** and **250°F** when entering the mixer.
   Aggregates heated beyond **325°F** shall be removed from the bins and may be cooled and reheated and used.
   Aggregates entering the mixer shall **not contain enough moisture** to cause foaming, slumping, or segregation of the mixture during hauling and placing operations.
4. Article 306.3.3-C – The tar shall be at a temperature between **175°F** and **225°F** when entering the mixer.
   Silicone liquid **may be added** to the tar in quantities and in manner approved by the Engineer, but **no payment** for silicone will be allowed.
   All tar received from the supplier at a temperature higher than **225°F** shall be cooled to between **175°F** and **225°F** prior to its use in the mixture, and tar heated at the Contractor's plant to a temperature above **225°F** shall be rejected and not used.
5. Article 306.3.3-D – The dry mixing time shall be between **5** and **10** seconds, and the total mixing period shall be the minimum time necessary for proper mixing and shall be between **30** and **60** seconds, as established by the Engineer.
6. **Article** 306.3.3-E – The following temperatures, in degrees Fahrenheit, shall be used for the tar concrete:

Aggregates	Min. **220** - - - Max. **250**
RT–12	Min. **175** - - - Max. **225**
Mixture when Laid	Min. **175**

7. Article 306.3.6-E – The tar shall be heated to a temperature of between **175°F** and **225°F** before it is used to coat existing construction.

APPENDIX C

Current Traffic Data

TABLE 8. TRUCK WEIGHT STUDY*

(KY 15, 1.3 miles east of KY 7 at
Jeff (Coal Tar Section), April 14, 1971)

VEHICLE TYPE	BODY TYPE	LOADED OR EMPTY	AXLELOADS (pounds)			TOTAL WEIGHT (pounds)
			FRONT	REAR	REAR	
14	Dump	E	12,740	8,720	8,800	30,260
14	Dump	E	12,800	6,840	6,840	26,480
14	Dump	E	12,100	8,800	8,800	29,700
14	Dump	L	7,920	22,260	21,260	51,440
14	Dump	L	14,340	31,080	33,260	78,680
14	Dump	E	14,360	7,080	7,120	28,560
14	Dump	L	15,680	30,160	30,760	76,600
14	Dump	L	14,680	27,920	29,120	71,720
14	Dump	E	12,700	7,380	7,400	27,480
14	Dump	L	14,220	28,720	27,220	70,160
14	Dump	L	15,520	30,900	30,140	76,560
14	Dump	L	8,500	19,760	21,080	49,340
14	Dump	L	15,880	31,160	31,880	78,920
14	Dump	E	11,400	8,260	8,000	27,660
14	Dump	L	15,820	29,080	25,000	69,900
14	Dump	E	12,240	8,620	9,000	29,860
14	Dump	L	13,500	25,800	26,480	65,780
14	Dump	L	16,280	32,300	29,840	78,420
14	Dump	L	15,460	24,820	31,020	71,300

*Division Planning, Card No. 7, State Code No. 27

TABLE 9. AVERAGE DAILY TRAFFIC*
(May 5-11, 1971)

SECTION	COUNTY	LOCATION	ADT
C-1	Perry	Jeff	4074
TAR	Perry	Jeff	3001
TAR	Perry	Vicco	2625
C-2	Knott	Red Fox	1741
C-2	Letcher	Isom	**

*Division of Planning, Portable Traffic Recorder Report
**Scheduled June 1971