Research Report
UKTRP-83-1

SANDSTONE AS A CONSTRUCTION MATERIAL
KY 80, Hazard to Watergap

by

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INTRODUCTION

KY 80 (Hazard to Watergap) was constructed using abundantly available crushed sandstone. The pavements were designed to have adequate load-carrying capibilities and stability but were considered to be experimental (see Figure 1). It was intended that performance would be monitored and that undesirable features and performance would be identified and studied. Such surveillance was discontinued before construction was completed.

Recently, the need has arisen for testing and evaluation of some of the experimental sections. Some spalls, scuffs, and artesian water have been observed. Excessive water has appeared in the shoulder, median, and mainline. There has been at least one spot failure.

Concern arises when a highway pavement becomes rough, potholed, or shows other defects. The public expresses concern through the news media or direct communications with government officials. The highway engineer, whether in design, construction, maintenance, or management, must be sensitive to these "seat-of-pants" analyses. The engineer is alerted in many ways to correct defects.

Innovative procedures and designs are subjected to field trials and evaluations. The evaluation of the performance of KY 80 is important relative to the determination of the effectiveness of the design and construction procedures and whether the method or system may become standard. Evaluation of performance will enable documentation of the experimental features, attributes, and designs and an assessment of the acceptability of those elements. Acceptability will be predicated on the absence of defects and(or) feasibility of achieving a satisfactory remedy for the defects found. The primary benefit is the evaluation of the performance and efficiency of the experimental pavements that might lead to greater service and potential cost savings in constructing and reconstructing highway pavements.

In the spring and summer of 1982, apparent deficiencies in the performance and behavior of some experimental pavement sections on KY 80 between Hazard and Watergap were observed. Spalls and blisters, perhaps as many as 40 or more, were reported after the 1981-82 winter. At a few sites, blistering had been induced by water bleeding through the surface. The pavement surface had reseated itself but retained tell-tale pie-shaped crack patterns. Even so, bleeding of water persisted nearby. Water had also emerged from contraction joints sawed into the concrete median curb and had in fact overflowed the lip of the curb in numerous places. In a few places, piping of water persists seemingly beyond the normal time and duration of rainwater infiltration and dissipation. Damage thus far has been only nominal.

The Kentucky Transportation Research Program was asked to submit a work plan to evaluate the performance of some experimental features. A plan was approved, and the investigations began on October 1, 1982. At this time, the

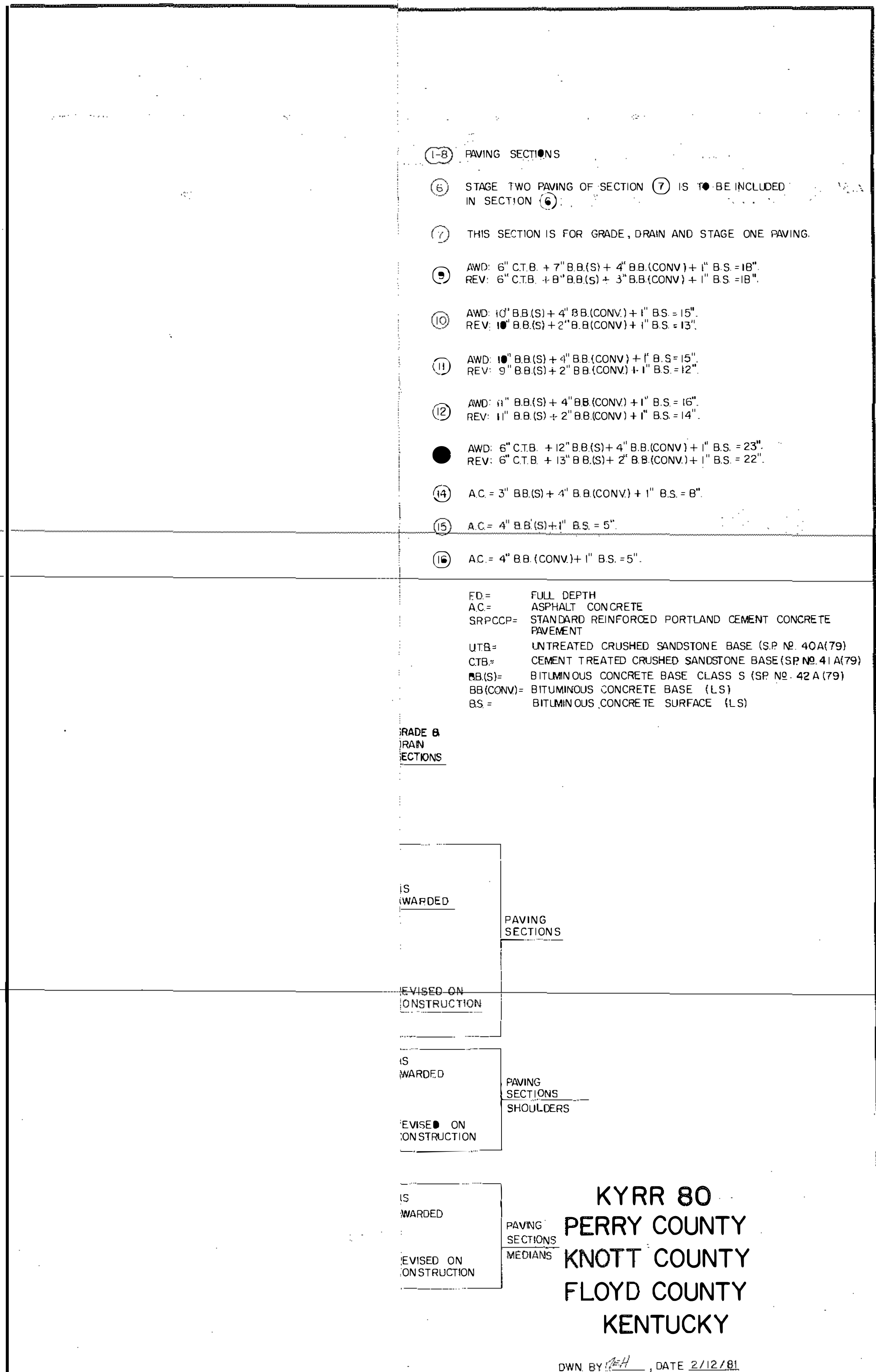


Figure 1. Layout Map of KY 80, Hazard-Watergap, Showing Pavement Sections and Project Information.

investigative work includes the section of KY 80 from Milepost 9 to Milepost 18. Some data were already available for sections near the Floyd-Knott County line. Those data were obtained in 1981 while conducting a study of in-place strength characteristics of sandstone rock subgrades. The investigation reported herein involved the following:

- condition survey and photologging;
- Road Rater testing and survey;
- coring, drilling, and sampling of pavement materials; and
- testing of cores and samples recovered from the pavement.

SUMMARY OF FINDINGS

GENERAL CONDITIONS

Figures 2 through 4 illustrate typical areas of distress that have been observed. There are a number of sites where water persistently emerges. For the most part, those sites occur slightly downgrade from cuts. It appears, therefore, that groundwater from cuts develop piping to the surface. The design of the raised median surrounded by concrete lip curbs provides opportunities for infiltration of surface water and a capacity for storage and facilitates the movement of water into embankments.

PAVEMENT CORES

Cores were obtained at ten locations on KY 80 in Knott County in the vicinities of Milepost 10 to 11, Milepost 13 to 14, and Milepost 18. Figures 5 and 6 are typical examples of photographs of all cores. Figure 5 illustrates the condition of cores when removed from the core barrel. The particular core shown was retrieved from the barrel in five pieces. All cores from mainline pavements showed such delaminations. Delamination was not observed in cores obtained from the median.

It is difficult to specifically determine the cause of the delamination of the layers in the pavement structure. Water was observed seeping from the limestone-sandstone interface at Milepost 18 (westbound inside lane). Water also was observed seeping from between all layers at Milepost 13.9 (westbound inside lane). The degree to which a tack coat was used, or not used, may be a factor. Unfortunately, the applications of tack on KY 80 were not determinable.

Thickness measurements of the cores were not possible because of the delamination. In many instances, sections of cores became wedged in the core holes and removal damaged the cores significantly. However, it was observed that the cores appeared to be representative of thickness design requirements. Typical sections are illustrated in Appendix A. A copy of the "Bituminous Concrete Thickness Report" prepared by the Division of Materials is included in Appendix B.

Figure 2. Station 4195 (Milepost 10.2), Looking Eastward; September 22, 1982.

Laboratory analysis of the cores included density determinations for each layer, permeability testing, and the determination of the ultimate Young's modulus of elasticity for each layer. Each core was sectioned according to layer type: asphaltic concrete surface (limestone aggregate), asphaltic concrete base (limestone aggregate), and asphaltic concrete base (sandstone aggregate).

Core Densities

Density measurements are summarized in Table 1. Target densities recommended by the Division of Materials were 152.2 pounds per cubic foot for asphaltic concrete containing limestone aggregate and 140.0 pounds per cubic foot for ashpaltic concrete containing sandstone aggregate. Section 403.04 of the **Kentucky Standard Specifications for Road and Bridge Construction**, 1979 Edition, requires in-place densities at least 95 percent of the job-mix formula density. A report (see Appendix B) prepared by the Division of Materials shows the average in-place density of one construction section to be 94.9 percent of the target density for asphaltic concrete containing limestone aggregate and 98.1 percent for asphaltic concrete cotaining sandstone aggregate.

It should be noted that above-target densities reported by the Division of Materials and the in-place densities found in the investigation reported herein were based on a small number of samples. This may account for differences between the reported data. These differences also may indicate isolated compaction problems during construction, and it may be those problem areas that are now showing distress.

The apparent lack of compaction of the median courses (see Table 1) may be the result of construction procedures. Crushing of the edge of the curb lip of the median was observed in numerous locations. This may be indicative of the roller riding on the edge of the curb lip and thus not applying the proper compactive effort to the asphaltic concrete. Possible causes of compaction problems of mainline paving have not been determined.

Permeability Testing

Six constant-head permeability tests were performed on selected specimens of the pavement cores. The specimens were "faced" by sawing and then were placed in a triaxial chamber. A rubber membrane sleeve was placed around the specimen and sealed by rubber o-rings at the top and bottom. A confining pressure of 70 psi was impressed on the specimens to prevent water leakage between the specimen and the rubber membrane. A back pressure of 60 psi was applied on the top and bottom of the specimens to ensure saturation of all voids in the specimen and drainage lines. The specimens were allowed to remain under these conditions for several hours before testing. At the start of the test, the back pressure was reduced to the predetermined head and the amount of water passing through the specimens were recorded from burette readings.

TABLE 1. SUMMARY OF DENSITY MEASUREMENTS

			DENSITIES (pounds per cubic foot)				
			MAINLINE PAVEMENT			MEDIAN PAVEMENT	
MILE-POST	DIRECTION	LANE	ASPHALTIC CONCRETE SURFACE (LIMESTONE)	ASPHALTIC CONCRETE BASE (LIMESTONE)	ASPHALTIC CONCRETE BASE (SANDSTONE)	ASPHALTIC CONCRETE SURFACE (LIMESTONE)	ASPHALTIC CONCRETE BASE (SANDSTONE)
10.6	Eastbound	Inside	134.0	134.7	136.4		
13.7						124.7	140.8
13.75						107.9	135.4
13.8						119.0	139.0
13.9	Westbound	Outside		145.7	139.0	132.2	137.0
					135.7		
		Inside	127.7	140.4	142.1		
	Eastbound	Inside	120.6	145.6	138.0		
					137.0		
18.0	Westbound	Inside		141.6	140.2		
Mean			127.4	141.6	138.3	123.2	137.8
Standard Deviation			6.7	4.5	2.3	10.2	2.1
Target Marshall Density			152.2	152.2	140.0	152.2	140.0
Percent of Marshall			83.7	93.0	98.8	80.9	98.5

The coefficient of permeability, k, was calculated from the following equation:

$$k = QL/Aht,$$

in which Q = quantity of water flow (cm^3),
L = length of flow path (length of specimen) (cm),
A = cross-sectional area of specimen (cm^2),
h = head loss (difference between the top back pressure and bottom back pressure) (cm), and
t = duration of test (sec).

Results are summarized in Table 2. It is immediately evident that the asphalt-bound limestone base is much more porous than the asphalt-bound sandstone base. The average coefficient of permeability for the three limestone specimens was approximately 4,700 times greater than that for the two sandstone specimens.

The coefficient of permeability for the sandstone specimen from the median was seven times greater (more porous) than the sandstone specimens from the mainline pavements. However, this is still approximately 650 times less than the average coefficient of permeability of the limestone specimens from the mainline.

Young's Modulus of Elasticity

The dynamic Young's modulus of elasticity was determined for selected layers of the pavement structure using the fundamental longitudinal frequency and the weight and dimensions of specimens obtained from the limestone and sandstone asphaltic concrete base courses. Two-inch diameter cores were taken from four limestone asphaltic concrete samples. Testing the larger 4-inch diameter sandstone samples was planned. However, problems were encountered with an accelerometer and determination of the resonant frequency was not possible. Thus, smaller-diameter (2-inch) specimens were used. There was no indication of problems with the testing of the smaller specimens.

Results of those tests are summarized in Table 3. The method of calculation is specified by ASTM C 215. In general, the modulus of elasticity of the sandstone asphaltic concrete was three to four times that for the limestone asphaltic concrete. It normally would be expected that the moduli of the two mixes would be similar.

It should be noted that the above information and discussion was based on a very small data base. Also, it is desirable that the height of the specimen be two to three times (2.3 is the optimum) greater than the diameter for the theory to be most applicable. It was not possible to maintain this ratio with the limestone specimens. Thus, additional testing of a larger sample (at least 30 specimens for each layer) is required for verification of the specific variations in moduli of elasticity. The data presented in Table 3 suggest an apparent difference between the two layers. Those apparent differences, however, also have been indicated by permeability testing and density determinations. It also should be noted that the moduli

TABLE 2. SUMMARY OF PERMEABILITY TESTS

LOCATION	MATERIAL	COEFFICIENT OF PERMEABILITY (cm/sec)
Milepost 13.9, Westbound Inside Lane	Limestone Base Mix	1.1×10^{-3}
Milepost 13.9, Eastbound Inside Lane	Limestone Base Mix	3.4×10^{-5}
Milepost 10.6, Eastbound Inside Lane	Limestone Base Mix	5.0×10^{-4}
Milepost 13.9, Westbound Inside Lane	Sandstone Base Mix	2.8×10^{-8}
Milepost 10.6, Eastbound Inside Lane	Sandstone Base Mix	2.1×10^{-7}
Milepost 13.75, Median	Sandstone Base Mix	8.3×10^{-7}

TABLE 3. SUMMARY OF YOUNG'S MODULUS OF ELASTICITY

SAMPLE IDENTIFICATION	MEAN LENGTH (inches)	MEAN DIAMETER (inches)	WEIGHT (pounds)	LONGITUDINAL FREQUENCY (Hertz)	DYNAMIC YOUNG'S MODULUS (psi)
MP 13.9, Eastbound Inside Lane Sandstone Asphaltic Concrete	4.264	2.242	1.356	12,600	2,406,602
MP 10.6, Eastbound Inside Lane Sandstone Asphaltic Concrete	4.776	2.247	1.539	13,100	3,293,704
Mean for Sandstone Asphaltic Concrete					2,850,171
MP 10.6, Eastbound Inside Lane Limestone Asphaltic Concrete	2.253	2.312	0.763	12,600	672,689
MP 13.9, Westbound Outside Lane Limestone Asphaltic Concrete	2.248	2.248	0.725	12,600	675,116
MP 13.9, Westbound Inside Lane Limestone Asphaltic Concrete	2.459	2.295	1.008	13,100	1,063,887*
MP 18.0, Westbound Inside Lane Limestone Asphaltic Concrete	2.196	2.251	0.728	12,900	691,376
Mean for Limestone Asphaltic Concrete					775,766
Mean for Limestone Asphaltic Concrete (with extreme value* omitted)					679,727

summarized in Table 3 are ultimate moduli and not design moduli.

Pavement Cross Sections

Cross sections were obtained at those sites where water was encountered in core and drill holes. Water was observed in holes at three locations near Milepost 14 and at one location near Milepost 10. Cross sections for those locations are presented in Figures 7 and 8.

Figure 7 represents conditions near Milepost 14 where water was observed at three locations. The levels at which the water stabilized in the holes were very nearly the same for all three holes. Also, the elevation was lower than the elevations observed for three locations where water was seeping from the cut face and flowing into the ditch. Two explanations are possible. First, other strata, such as a coal seam, have been intercepted and are directing water into the subgrade at this location. Since seepage has been observed for other strata, the potential for other aquifers apparently exists. Site conditions at Milepost 14 illustrate this possibility. Secondly, ditch lines were observed to be clogged in at least one location in this area. Shortly after a rain, water was observed flowing under fallen debris in the ditch. The water did not reappear for some considerable distance downgrade. It is possible that water from the ditch is moving laterally (piping) under the pavement.

Figure 8 illustrates conditions near Milepost 10. Water was found in one of three core holes in the median up to two days after a rain. Inspection of the other two holes indicated water had been present in the holes, but it could not be ascertained whether the water was from surface runoff or from groundwater. The drill hole containing water was located at the beginning (western end) of a superelevated section. There was also some ponding in the ditch. The cut face and ditch line were higher than the water in the drill hole in the median. A small amount of seepage was observed on the embankment slope downhill from the median drill hole. Therefore, it is possible that water is moving from the ditch on the high side of the superelevated section underneath the pavement and exiting on the embankment slope on the low side of the section. Water also was observed flowing from the base of the embankment at the eastern end of this same superelevated section (approximately 1,300 feet east). Water flowing from the embankment was reddish brown (rusty), possibly an indication of the movement of subterranean water through the embankment.

ROAD RATER SURVEY

The Road Rater was used for detailed deflection testing of three sites on KY 80 in Knott County. Testing at intervals of 100 feet or less was conducted in each of the four lanes and in the median. The same procedures were used for all test sites. Deflection data were analyzed using procedures previously developed and involved expressing the behavior of the pavement structure in terms of an effective

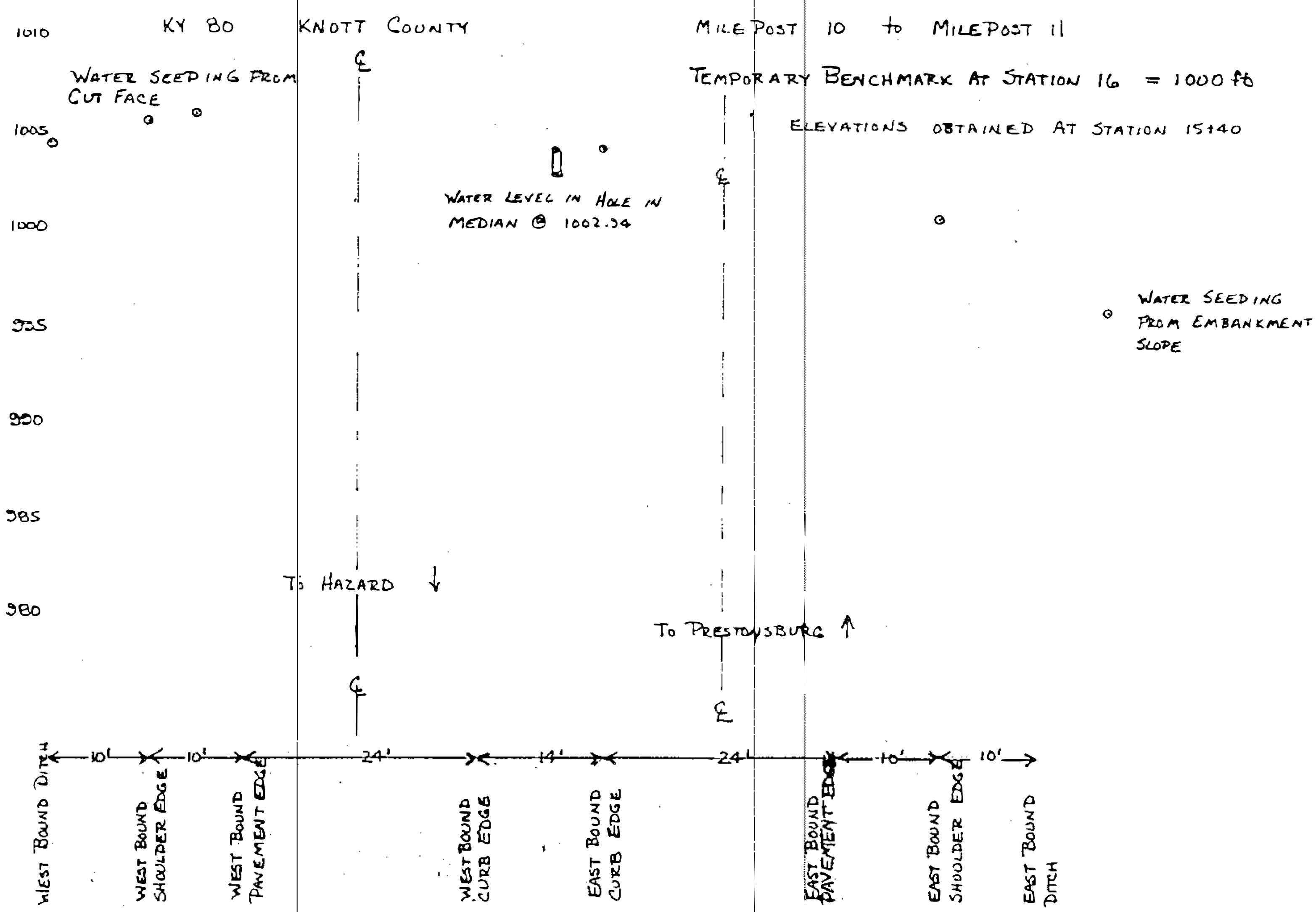


Figure 7. Association of Seepages and Groundwater Elevations with Roadway Cross Section at Milepost 10 to Milepost 11.

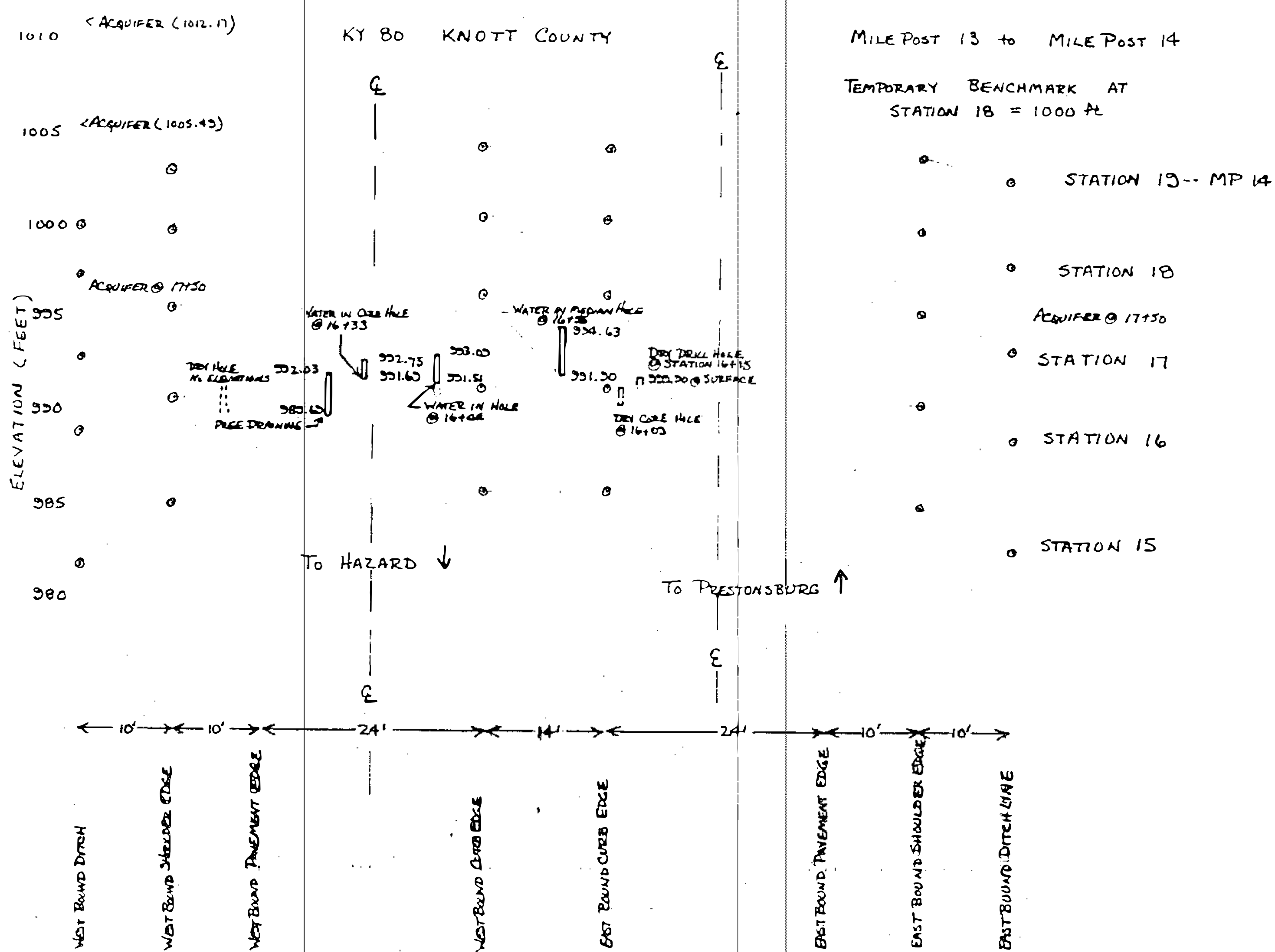


Figure 8. Association of Seepages and Groundwater Elevations with Roadway Cross Section at Milepost 13 to Milepost 14.

thickness of reference quality asphaltic concrete and a predicted subgrade strength (modulus of elasticity). Tables 4 through 6 summarize test results from the three sites. Estimates of the CBR's are determined by dividing the predicted modulus (in psi) by 1500.

A fourth series of deflections was obtained from a survey of each lane and the median from Milepost 9 to Milepost 16. Test data were obtained at 0.2-mile intervals and were staggered such that at least one deflection measurement was obtained for each 0.1 mile. A summary of the results of this survey are presented in Table 7.

Road Rater deflections measurements also were obtained at randomly selected "wet spots" between Milepost 10 and Milepost 11. Results are summarized in Table 8.

Analysis of Road Rater data indicated considerable variability in deflection behavior among the test sites. Such large variations may be due in part to the presence of water in any or all of the component layers of the pavement. Data obtained from the median indicated overall weak behavior. Estimates of the modulus of elasticity of the median materials were very low and may indicate the presence of water in the median. Low values of the modulus of elasticity also may reflect poor compaction resulting from the roller riding on the lip of the concrete curb, as noted previously. Estimates of the effective thicknesses indicate that the asphaltic concrete in the median is in "good" condition.

Direct comparison of data in Tables 4 through 8 was difficult since pavement behavior for each section was expressed as a combination of the effective thickness of asphaltic concrete and an estimate of the subgrade modulus. The Kentucky 480-ksi design curves for full-depth asphaltic concrete were used to make estimates of the expected remaining fatigue life for each section. The number of 18-kip equivalent axleloads (EAL's) corresponding to the combination of effective thickness and subgrade modulus was read from the design curves. The remaining EAL's can be used to compare the various sections tested.

There was considerable variability throughout for all test sections, indicating extremes of pavement structures performing well and poorly. In most locations, the inside (median) lane showed the weaker behavior. Tests in wheelpaths adjacent to the shoulder generally showed stronger behavior. Table 5 summarizes data for a superelevated section with the eastbound lanes at the lower elevations. Road Rater testing in that section (Milepost 10.2 to Milepost 10.8) indicated weaker behavior in the eastbound lane.

Road Rater data obtained at wet spots (Table 8) between Milepost 10.2 and Milepost 10.8 were compared to performance data obtained at locations showing no distress (Table 5) in the same length of roadway. The loss in remaining fatigue life in the wet spots was equivalent to 3/4 to 1 inch of thickness of asphaltic concrete.

TABLE 4. RESULTS OF DEFLECTION TESTS: MILEPOST 10.0 TO MILEPOST 10.08

TEST LOCATIONS			SUBGRADE MODULUS (psi)			EFFECTIVE ASPHALTIC CONCRETE THICKNESS (inches)	
DIRECTION	LANE	WHEELPATH	MEAN	STANDARD DEVIATION	CBR	MEAN	STANDARD DEVIATION
Westbound	Outside	Outside	28,600	7,750	19.1	9.78	2.43
Westbound	Inside	Inside	24,700	5,900	16.5	9.27	2.21
Median			5,260	420	3.5	4.29	0.29
Eastbound	Inside	Inside	30,400	17,600	20.3	8.72	2.46
Eastbound	Outside	Outside	20,260	11,300	13.5	10.86	1.35

Asphaltic Concrete Thickness Design
Mainline Pavement 13.0 inches
Median Pavement 5.0 inches on 11.0 inches of untreated Sandstone

Remaining Fatigue Life (Equivalent 18-kip Axleloads)
(from 480-ksi full-depth design curves)

Westbound Outside Lane, Outside Wheelpath	5,400,000
Westbound Inside Lane, Inside Wheelpath	3,200,000
Eastbound Inside Lane, Inside Wheelpath	3,000,000
Eastbound Outside Lane, Outside Wheelpath	5,600,000

TABLE 5. RESULTS OF DEFLECTION TESTS: MILEPOST 10.2 TO MILEPOST 10.8

TEST LOCATIONS			SUBGRADE MODULUS (psi)			EFFECTIVE ASPHALTIC CONCRETE THICKNESS (inches)	
DIRECTION	LANE	WHEELPATH	MEAN	STANDARD DEVIATION	CBR	MEAN	STANDARD DEVIATION
Westbound	Outside	Outside	27,640	10,230	18.4	10.36	1.78
Westbound	Inside	Inside	34,960	14,900	23.3	10.53	1.97
Median			6,030	1,670	4.0	2.97	0.81
Eastbound	Inside	Inside	31,600	16,500	21.1	9.84	2.42
Eastbound	Outside	Outside	36,840	18,240	24.6	9.24	1.98

Asphaltic Concrete Thickness Design

Mainline Pavement 13.0 inches

Median Pavement 5.0 inches on 11.0 inches of untreated sandstone

Remaining Fatigue Life (Equivalent 18-kip Axleloads)
(from 480-ksi full-depth design curves)

Westbound Outside Lane, Outside Wheelpath	7,600,000
Westbound Inside Lane, Inside Wheelpath	11,000,000
Eastbound Inside Lane, Inside Wheelpath	6,900,000
Eastbound Outside Lane, Outside Wheelpath	6,200,000

TABLE 6. RESULTS OF DEFLECTION TESTS: MILEPOST 13.6 TO MILEPOST 14.0

TEST LOCATIONS			SUBGRADE MODULUS (psi)			EFFECTIVE ASPHALTIC CONCRETE THICKNESS (inches)	
DIRECTION	LANE	WHEELPATH	MEAN	STANDARD DEVIATION	CBR	MEAN	STANDARD DEVIATION
Westbound	Outside	Outside	20,210	5,670	13.5	11.04	1.29
Westbound	Inside	Inside	20,550	5,510	13.7	10.09	1.42
Median			5,180	1,010	3.5	4.14	0.57
Eastbound	Inside	Inside	24,670	9,850	16.4	8.89	1.66
Eastbound	Outside	Outside	20,740	7,300	13.8	10.56	1.51

Asphaltic Concrete Thickness Design
Mainline Pavement 13.0 inches
Median Pavement 5.0 inches on 11.0 inches of untreated Sandstone

Remaining Fatigue Life (Equivalent 18-kip Axleloads)
(from 480-ksi full-depth design curves)

Westbound Outside Lane, Outside Wheelpath	7,200,000
Westbound Inside Lane, Inside Wheelpath	4,000,000
Eastbound Inside Lane, Inside Wheelpath	2,500,000
Eastbound Outside Lane, Outside Wheelpath	5,600,000

TABLE 7. RESULTS OF DEFLECTION TESTS: MILEPOST 9.0 TO MILEPOST 16.0

TEST LOCATIONS			SUBGRADE MODULUS (psi)			EFFECTIVE ASPHALTIC CONCRETE THICKNESS (inches)	
DIRECTION	LANE	WHEELPATH	MEAN	STANDARD DEVIATION	CBR	MEAN	STANDARD DEVIATION
Westbound	Outside	Outside	24,600	14,160	16.4	10.31	1.78
Westbound	Inside	Inside	28,220	13,850	18.8	8.64	1.80
Median			6,860	4,890	4.6	4.25	0.84
Eastbound	Inside	Inside	27,950	13,420	18.6	8.57	1.78
Eastbound	Outside	Outside	19,930	9,360	13.3	10.53	1.55

Asphaltic Concrete Thickness Design

- Mainline Pavement 13.0 inches
- Median Pavement 5.0 inches on 11.0 inches of untreated Sandstone

Remaining Fatigue Life (Equivalent 18-kip Axleloads)
(from 480-ksi full-depth design curves)

Westbound Outside Lane, Outside Wheelpath	6,200,000
Westbound Inside Lane, Inside Wheelpath	2,500,000
Eastbound Inside Lane, Inside Wheelpath	2,300,000
Eastbound Outside Lane, Outside Wheelpath	4,900,000

TABLE 8. RESULTS OF DEFLECTION TESTS: MILEPOST 10.2 TO MILEPOST 10.8
RANDOM WET SPOTS

TEST LOCATIONS			SUBGRADE MODULUS (psi)			EFFECTIVE ASPHALTIC CONCRETE THICKNESS (inches)	
DIRECTION	LANE	WHEELPATH	MEAN	STANDARD DEVIATION	CBR	MEAN	STANDARD DEVIATION
Eastbound	Outside	Outside	34,190	13,215	22.8	8.64	2.39

Asphaltic Concrete Thickness Design
- Mainline Pavement 13.0 inches
- Median Pavement 5.0 inches on 11.0 inches of untreated Sandstone

Remaining Fatigue Life (Equivalent 18-kip Axleloads)
(from 480-ksi full-depth design curves)
Eastbound Outside Lane, Outside Wheelpath 3,200,000

Analysis of Geologic Conditions

Plan-profile drawings were used to superimpose the location of KY 80 onto the Hindman and Handshoe geologic quadrangle maps. A detailed field inspection was made to verify specific landmarks to confirm the route location on the maps. During the field inspection, detailed notes were made of water seepage on cut faces and of areas where wet spots were, or had been, observed on the pavement surface. Seepage locations were color coded on the quadrangle maps in green, and the wet areas on the pavement were denoted in red. The centerline of the route was marked in black. The red and(or) green colors were placed on the appropriate side of the black centerline.

A strip chart (Figure 9) was prepared to show the profile of the pavement in relation to the geologic profile along the centerline. At the top of the strip chart are the approximate mileposts. The next lower line locates the seepage zones on the north cut faces. The next line down locates areas of wet pavement in the westbound lanes. The center of the chart is the profile. The line below the profile shows areas of wet pavement in the eastbound lanes, and the next lower line locates water seepage areas on the south face. The bottom line locates the data by station.

The entire length of KY 80 studied in this investigation lies in the Breathitt Formation. From the Hindman connector to approximately Milepost 15.5, KY 80 is located in the upper half of the Breathitt Formation. In this region, outcropping coal seams were identified as the Francis, Hazard No. 7, and Hazard. Near Milepost 11, the Hindman coal was the highest visible from the highway. Those coal seams usually are interbedded with thin shale layers. Descriptions given in the columnar sections of the geologic maps show each of those coal seams underlain with a relatively impervious plastic clay layer containing kaolinite. Thus, there is a potential for a perched water table, and water will move laterally along those layers.

From Milepost 15.5 to Milepost 18, the profile progresses downward into the lower portion of the Breathitt Formation. Outcropping coals there were identified as the Haddix, Fire Clay, and Amburgy. According to the geologic descriptions, only the Haddix does not have a plastic underclay. Thus, water potentially can drain vertically through that coal seam.

During an inspection of KY 80 after a rainy period, locations of water seepage were recorded and located by milepost. Every wet area observed could be associated with those coal seams.

The general slope of the bedding planes from the geologic maps is to the northwest. However, based on visual observations, there are a few locations where the dip of the beds appeared to be to the southeast. Where bedding planes dipped downward to the northwest, seepage zones usually were seen on the southeast face of a rock cut. Where the beds dipped to the southeast, seepage zones were observed on the northwest faces of rock cuts. Where bedding planes appeared

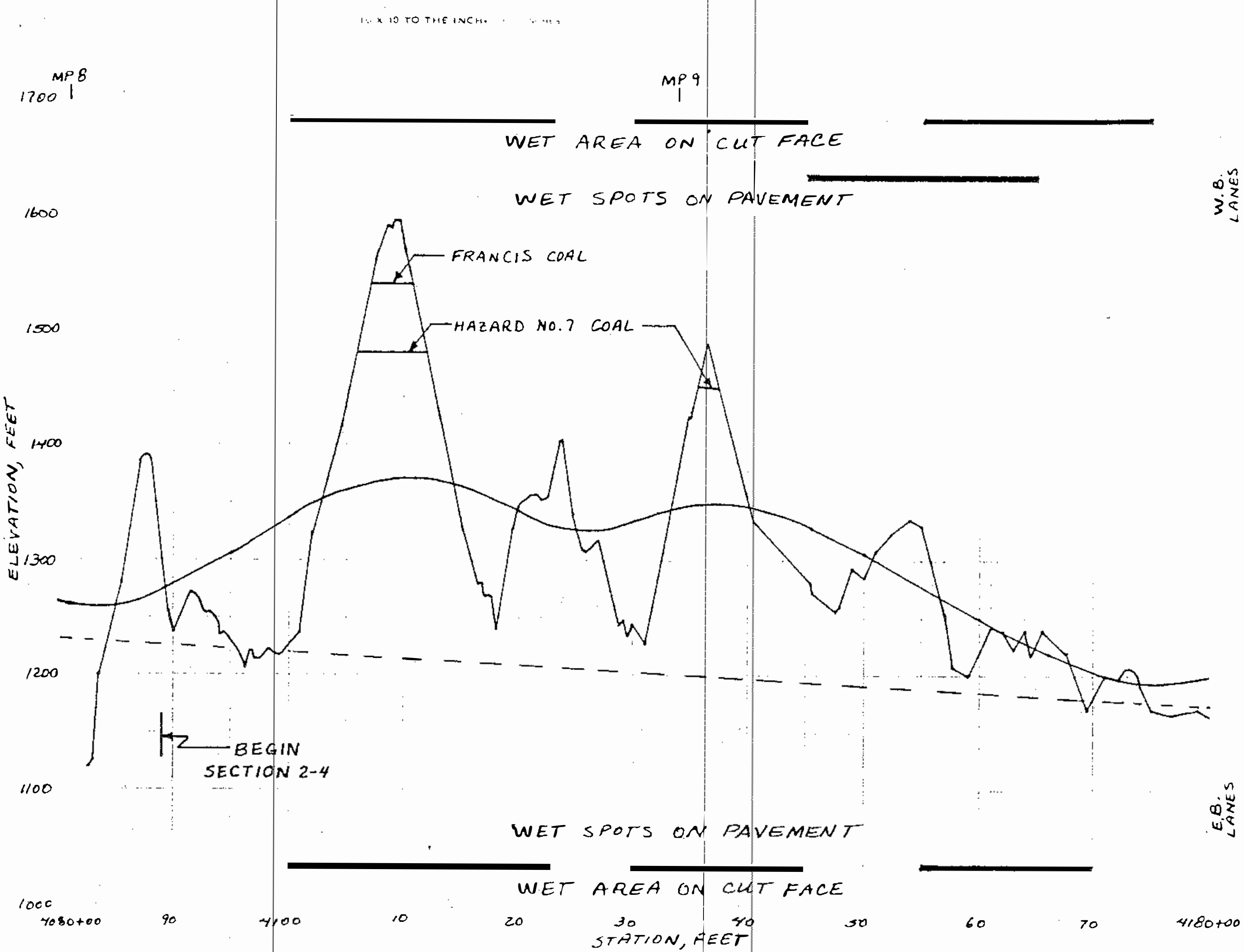
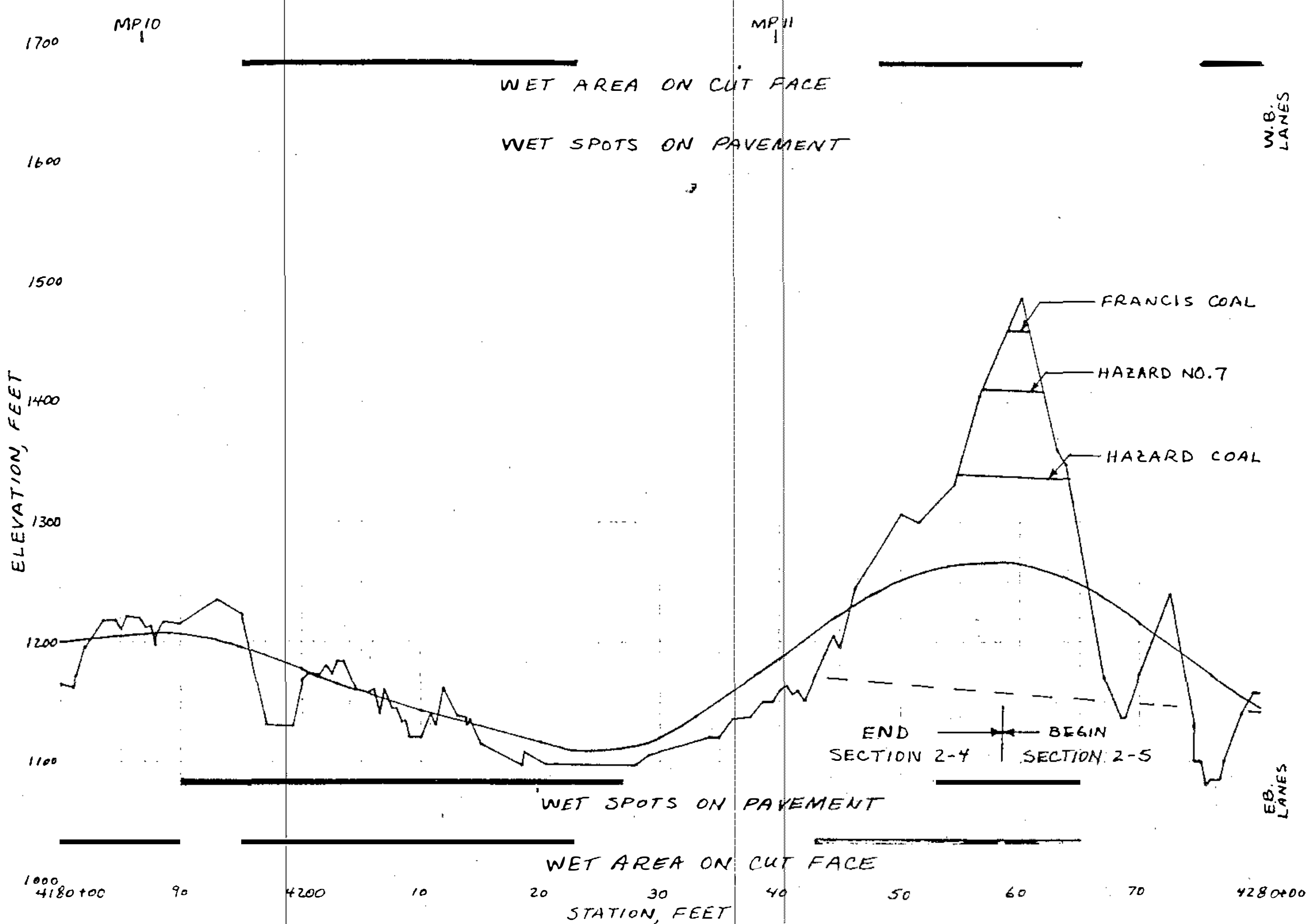


Figure 9. Association of Seepages with Geological Stratification and Outcroppings.



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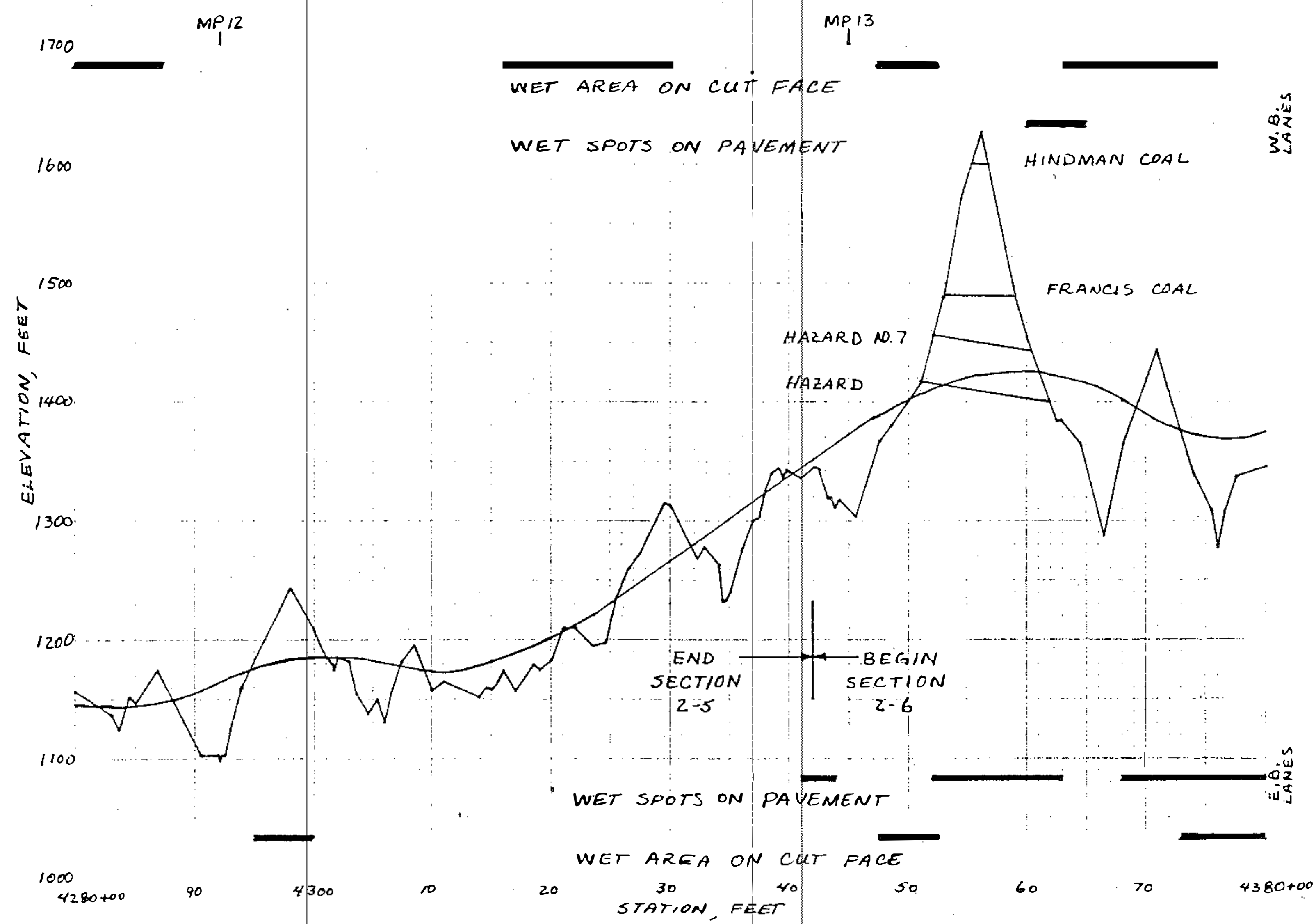

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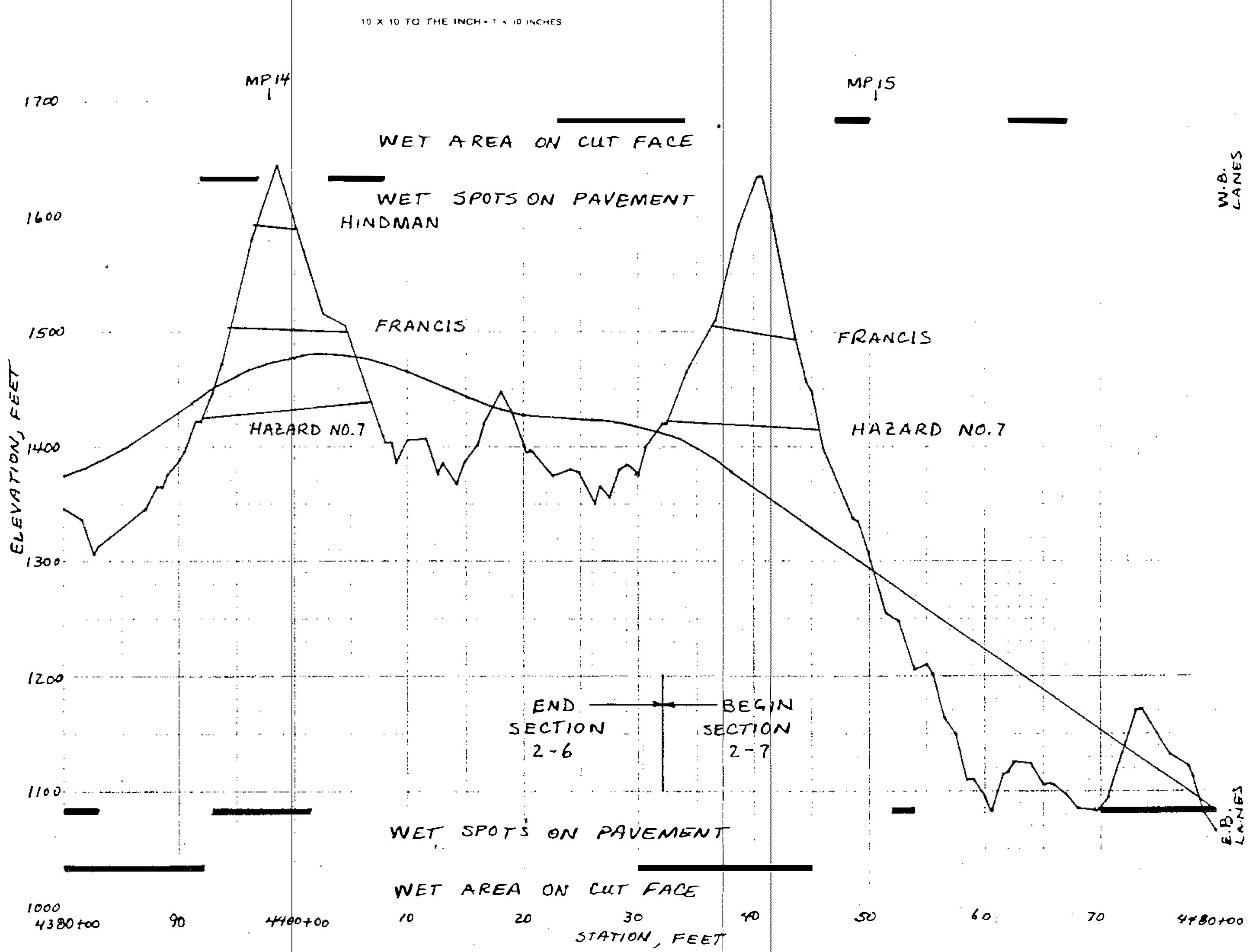

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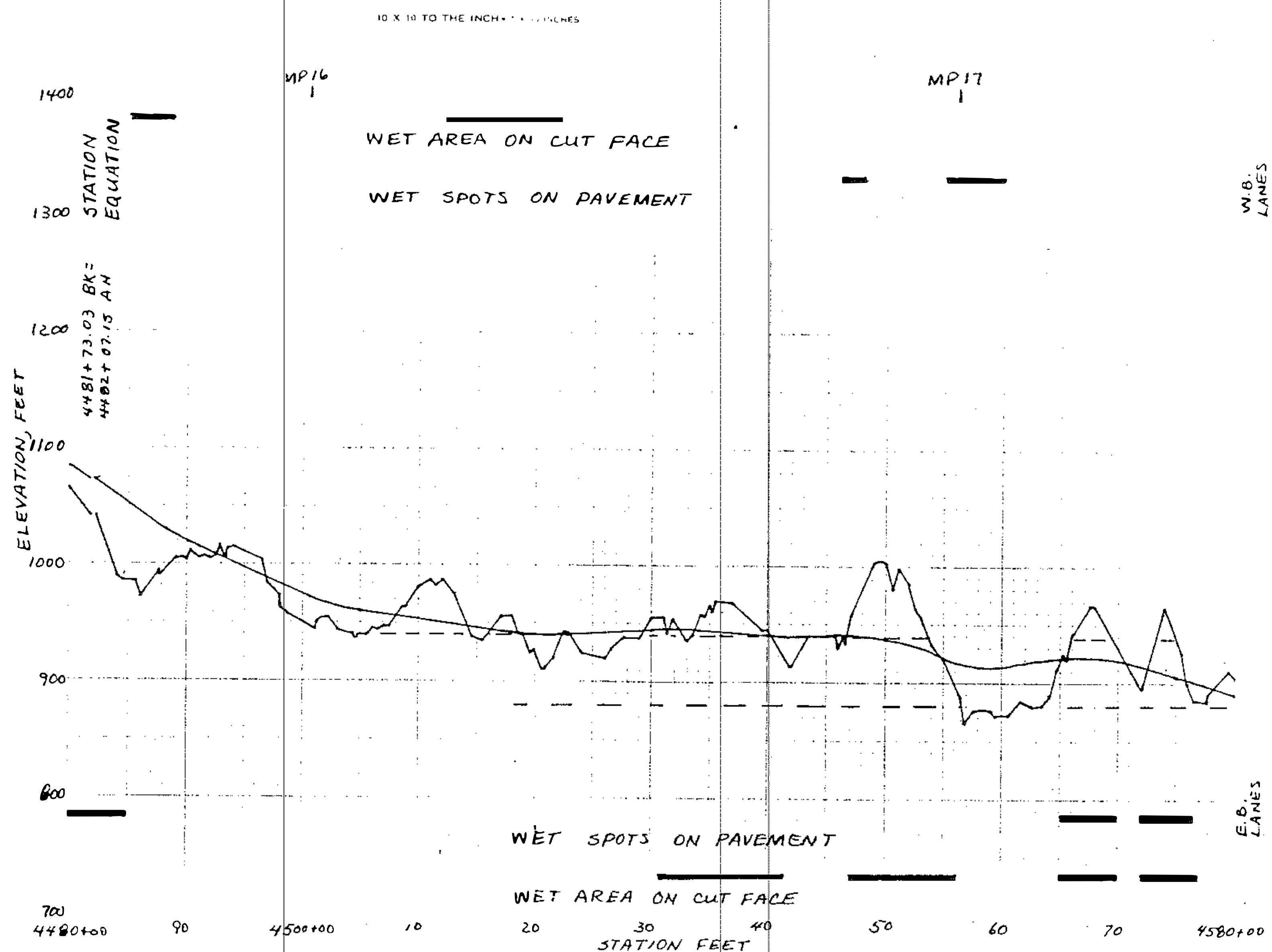

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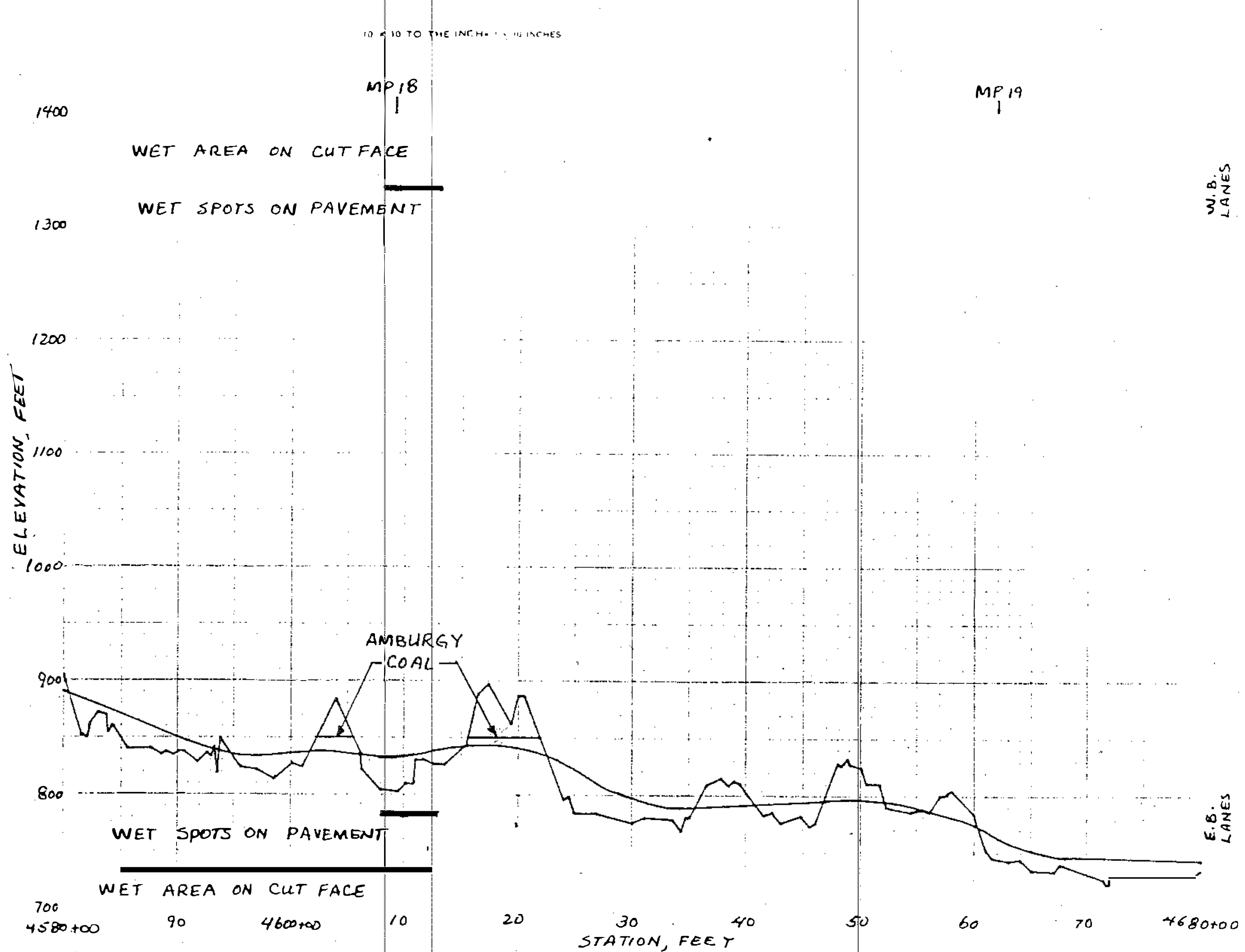

Figure 9. Continued.

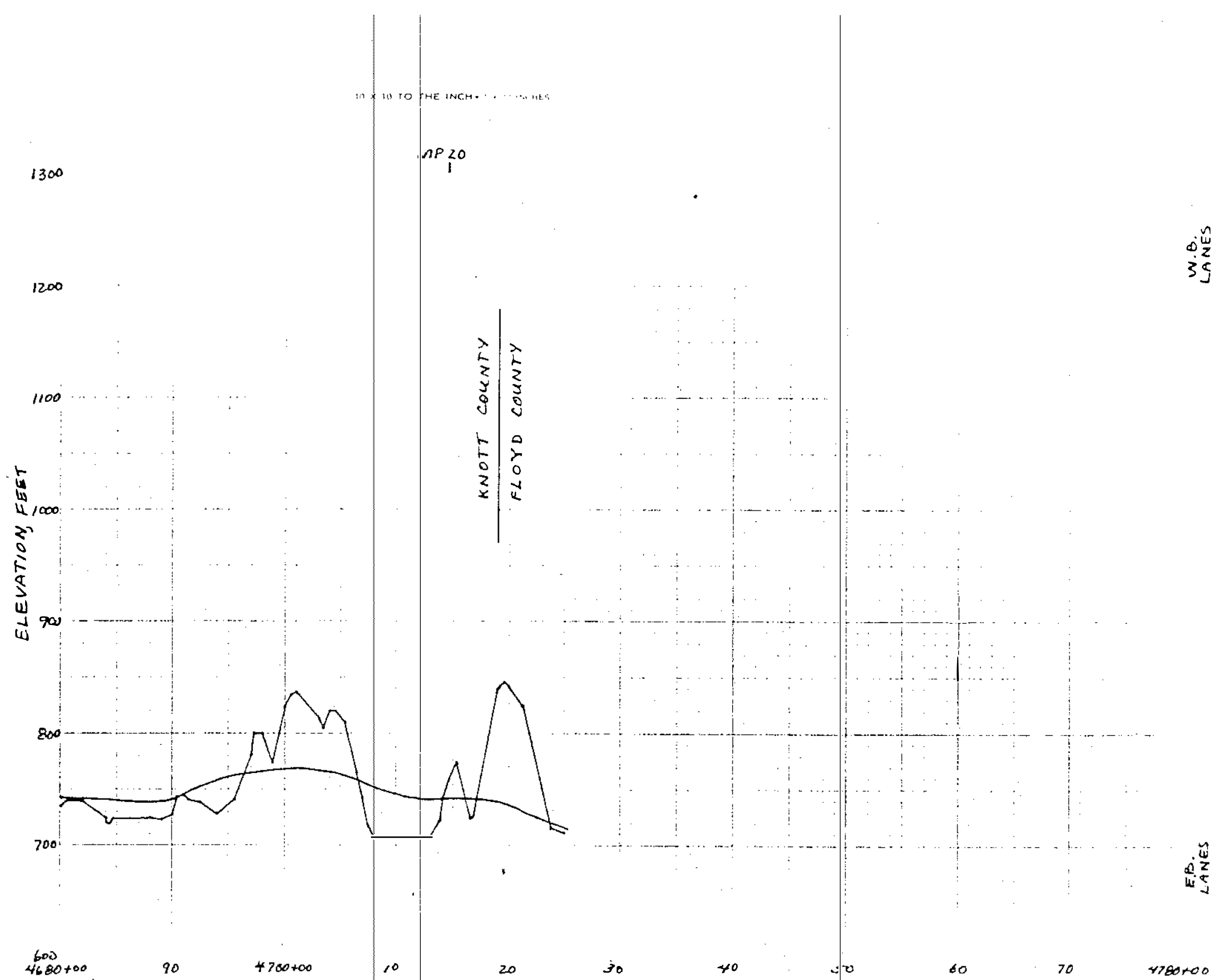

Figure 9. Continued.

to be nearly level, seepage could be observed on both faces of a rock cut.

Because plastic underclays will not permit groundwater to drain vertically, the water must move laterally through the interbedded coals and shales. When a highway cuts through the bedding, the water outcrops and moves down the face of the cut and eventually into the ditches.

A shale generally is composed of thin, parallel layers of water-deposited materials. During later geologic times, these layers may have been cracked and broken, thus permitting small channels to form through which water can move. Thus, depending upon the exposed layers in the ditch lines, water might enter the shales and move laterally to areas under the pavement. Conditions could exist so the water is held under the pavement and drains in the direction of the downgrade of the highway. Thus, water pressures increase until zones of weaknesses permit the water to escape either to the side or upward toward the surface of the pavement. Therefore, ditch lines become an important design element in the potential performance of pavements. Ditches should be designed to drain parallel to the centerline and to be deep enough to prevent intrusion of water into the area immediately beneath a pavement.

Field inspection indicated that zones of water seepage from coal or shale layers existed throughout the length of pavement under study, as shown in green on the geologic quadrangle maps. Furthermore, wet spots in the pavement (denoted in red on the geologic maps) also existed throughout the study area. Since Milepost 18 was located in a section paved by another contractor, the problem of wet spots in the pavement cannot be attributed to a specific contractor, but probably is evidence of a general geologic phenomenon in that area of Kentucky. Samples of the subgrade were obtained at Milepost 13.9 and 10.6. The materials appeared to be a degraded sandstone at both locations. A visual inspection indicated that the materials were damp but not saturated.

SUMMARY AND CONCLUSIONS

SOURCES AND FLOW OF WATER

Emergent water has no apparent relationship to the use of sandstone as a construction material. Seepage of water on KY 80 should not in any way deter uses of sandstone for future highway construction.

Most coal seams (five of six) exposed in cuts along the study area are underlain with an impervious, plastic clay. Thus, there is a potential for perched water and for the lateral movement of groundwater over long distances.

Groundwater is one apparent source of water found in the study area. Such water might move laterally to areas under the pavement. Surface water and groundwater may also move laterally from relatively flat and shallow ditches.

Sawed joints in the median curbs permitted water movement downward into the pavement structure or served as an outlet for subsurface waters, depending upon the specific locations.

ASPECTS OF THE MEDIAN DESIGN

Unsurfaced raised medians, such as those used on the Versailles-Frankfort Road, the New Circle Road in Fayette County, the Bluegrass Parkway, and elsewhere, have generated seepages and artesian spouts in the roadway. Water entering the median through the grassy surface or through cracks will find or make an exit.

Similar seepages and artesian spouts also have been observed on KY 80. The design of the median is such that any water trapped in the median may rise to the elevation of the bottom of the asphaltic concrete surfacing in the median. Excess hydrostatic pressures will result in forced movement of water through sawed joints in the median curbs or under the curbs and into the pavement structure. Water also may be ejected from the pavement-curb interface.

Broken sandstone backfill in the median permits relatively easy movement of waters accumulated over large areas of pavement and adjacent roadsides. The sandstone backfill may also allow for the storage of large quantities of water that must eventually escape or be the source of problems.

Internal drainage of the median surely would have been enhanced by providing bleeders through the back wall of the median curb inlet boxes (see Appendix A). Seepage also might have been provided through the outside wall and from under the pavement layers.

ASPECTS OF THE DITCHES

Several locations were observed where the ditch lines had become clogged. Therefore, the potential for lateral movement of water from the ditch to the pavement structure or the median exists. Water "sinks" and ponding were found in the side ditches in the cuts and near transitions to fill sections. "Sinks" should be sealed, and paving of the ditch line and(or) installation of perforated pipe may be needed.

It appeared at a few sites that ledge rock and shale layers had not been undercut sufficiently in the ditch line.

CONSTRUCTION CONSIDERATIONS

In the median, the roller compacted the asphaltic concrete until the drum of the roller came into contact with the concrete curb. The curb then failed in compression at the usual angle of about 15 degrees, creating cracks through which water could move, however slowly that might be. Had the uncompacted asphaltic concrete extended farther above the concrete curb, the roller might not have come into contact with the curb. Where this was the case, the interface between the asphaltic concrete and the curb appears to be tight and in good condition.

Heavy coal trucks and construction traffic traveling on the rock subgrade may have worn and compacted a dense impervious crust. After paving, this crust would tend to perch water there and to otherwise interfere with free drainage.

There was no evidence of undesirable or deleterious materials found in the core and auger holes.

There was an apparent lack of asphaltic tack between layers of the pavement structure.

Wet areas in the pavement were observed throughout the study area, which covered paving by two contractors. Thus, the problem does not seem to be attributable to a single contractor.

MATERIALS

Laboratory tests showed the asphaltic concrete containing sandstone aggregate to be relatively impervious. The asphaltic concrete utilizing limestone aggregate was approximately 4,700 times more permeable (porous).

While coring the pavement, water was observed to move through the pavement structure in a number of ways:

a. through the asphaltic limestone concrete layers,
b. at the interfaces between layers of asphaltic concrete,
c. through finger-sized channels in untreated sandstone base layers (piping), and
d. on top of the sandstone subgrade at the interface between the subgrade and an asphaltic concrete layer.

No water was observed to be moving through the asphaltic concrete courses made of sandstone aggregate.

Cores extracted from the pavement separated and delaminated at the interfaces between the various courses of asphaltic concretes. This seems to support the conclusion that tack coats were used sparingly.

POSSIBLE CORRECTIVE MEASURES

Install cutoff drains at the outside edge of shoulders where needed. A depth of at least 5 feet below shoulder grade is recommended to keep free water below the elevation of the subgrade and the asphalt-bound layers. Perforated pipe with a free-draining backfill filter should be included as part of the design. It is recommended that these pipe be placed along both shoulders in cuts on tangent sections and on the "high" side of superelevated sections. The following sections appear to be the most critical:

1. Station 4120 to Station 4225,
2. Station 4350 to Station 4375,
3. Station 4390 to Station 4410, and
4. Station 4560 to Station 4625.

Construct median drains at least 8 inches into the sandstone subgrade. However, it is preferable that the drain pipe be placed at the base of the sandstone subgrade. It is recommended that these drains be placed only in the most critical locations:

1. Station 4145 to Station 4170,

2. Station 4190 to Station 4225,
3. Station 4340 to Station 4410,
4. Station 4440 to Station 4500, and
5. Station 4560 to Station 4615.

Modify some of the drop-inlet boxes of median curb drains to allow the longitudinal median drains recommended above to drain into them.

In an attempt to prevent water from entering the median through the curb-median pavement interface, a slurry seal or even a 3/4-inch resurfacing might be used. In those locations where collector pipes are installed in the median, consideration should be given to removing the median surface and some of the untreated sandstone base. That material could be recycled and relaid and compacted so that the asphaltic surface would be slightly above the curb to ensure proper compaction.

Inasmuch as the suggested corrective measures are concerned with controlling and handling undesirable water that may get into the pavement structure, consideration might be given to staging the remedial measures. First, either the median drains or the cutoff drains in the ditch lines might be installed. An economic analysis might assist in deciding which should be done first. However, the cutoffs in the ditch lines would probably be the most successful in eliminating excess from the pavement structure. If the first stage is successful in controlling excess waters, the other measures need not be implemented. On the other hand, other corrective measures may be necessary.

It should be noted that there is a potential for similar problems throughout similar projects in Eastern Kentucky. Distress in other areas may not yet be apparent in visual inspections.

Designs of any engineering structure should involve the assessment of risks associated with various levels of design and construction. It is possible to design and construct facilities that would be essentially free of failure; such designs, however, would be costly initially. At the other extreme, the design and construction could be minimal, and thus less costly initially; but there would be a high risk of failures requiring costly repairs. The better design is probably between these extremes, where there is an optimum balance between initial and long-term costs. Some failures would be expected (and allowed), and repairs would be made after the occurrences. The actual design and construction of the pavement drainage system on KY 80 may be nearer the minimum initial cost extreme than the optimum design.

It also should be noted that design options are greater in the initial planning and design of a facility. For example, the ditches on KY 80 could have been deeper and wider. But such a design would have required more extensive excavation and thus would have been more costly. With the roadway already in existence, however, that design option may not be as viable. Remedial measures must begin with the facility as it exists.

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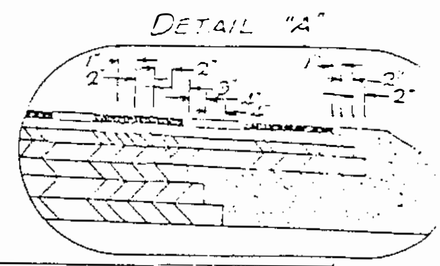
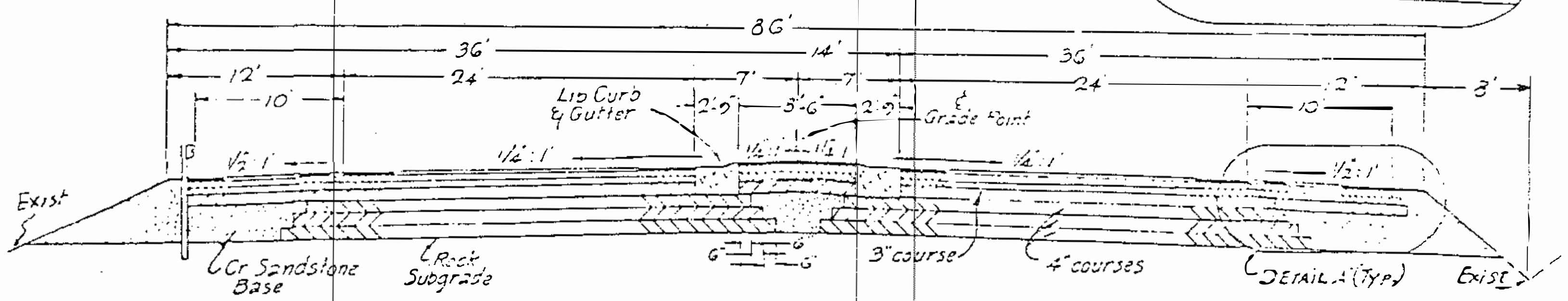
APPENDIX A

TYPICAL SECTIONS

FULL-DEPTH ASPHALTIC CONCRETE

STA 812+16 To STA 901+67





Approx 20" Pavement:

- Approx 19" Base — 15"± Compacted Depth Bituminous Concrete Base - Class S (3-4" & 1-3" course) - Spec. Prov No. 42 (76); 4"± Compacted Depth Bituminous Concrete Base (2-2" courses)
- Tack Coat — 0.8 Lbs. per sq. yd. Apply as directed
- Surface — 1"± Compacted Depth Bituminous Concrete Surface

Paved:

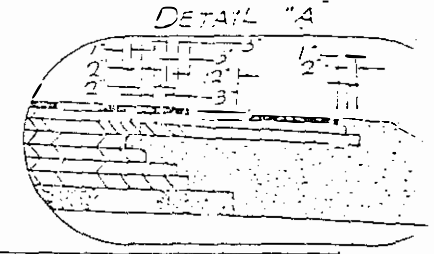
- Median - Approx. 23"
- Shoulders - Approx 20"

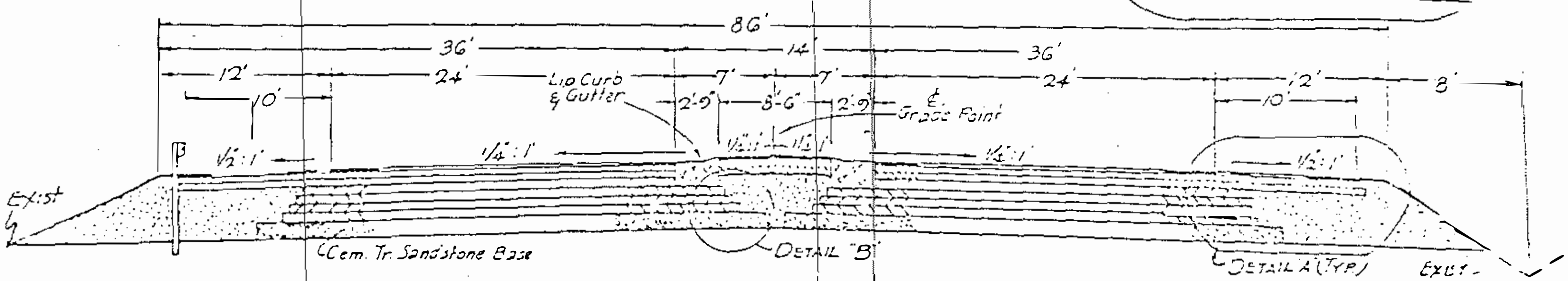
Full Depth Compacted Crushed Sandstone Base - Spec. Prov No. 40 (76)
3"± Compacted Depth Bituminous Concrete Base - Class S - Spec. Prov No. 42 (76)
4"± Compacted Depth Bituminous Concrete Base (2-2" courses)
0.6 Lbs per sq yd Tack Coat. Apply as directed
1"± Compacted Depth Bituminous Concrete Surface

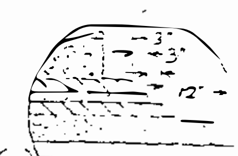
Note: 1" B.C. Base Deferred to 1" Surface, FROM KY. 777 TO EAST OF WARGO (STA 890+00±)

ASPHALTIC CONCRETE ON CEMENT-TREATED SANDSTONE BASE

STA. 901+67 TO STA. 1275+20







DETAIL "B" (Typ)

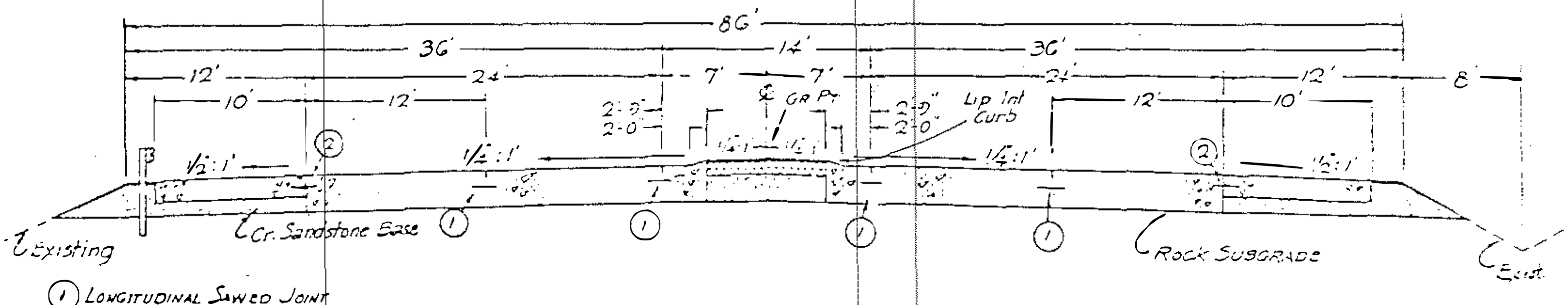
Approx. 22" Pavement —
- Approx. 21" Base —
  - 6"± Compacted Depth Crushed Sandstone Base - Cement Treated - Spec. Prov. No. 41 (76)
  - 11"± Compacted Depth Bituminous Concrete Base - Class S (2-3" courses) Spec. Prov. No. 42 (76)
  - 4"± Compacted Depth Bituminous Concrete Base (2 - 2" courses)
- Tack Coat — 0.8 Lbs. per sq. yd. Apply as directed.
- Surface — 1"± Compacted Depth Bituminous Concrete Surface,

Paved —
- Median - Approx. 30"
- Shoulders - Approx. 22"
  - Full Depth Compacted Crushed Sandstone Base (Spec. Prov. No 40 (76)
  - Compacted Depth Bituminous Concrete Base - Class S (Spec. Prov. No. 42 (76)
  - 4"± Compacted Depth Bituminous Concrete Base (2-2" courses)
  - 0.8 Lbs. per sq. yd. Tack Coat. Apply as directed.
  - 1"± Compacted Depth Bituminous Concrete Surface

From Sta. 1036+00: Shoulder is 8" B.C. on 14" sandstone.
Median is 8" B.C. on 17" Sandstone

FULL-DEPTH PORTLAND CEMENT CONCRETE

STA. 3231+30 To STA. 3328+00



① Longitudinal Sawed Joint

② Longitudinal Sawed Const. Joint

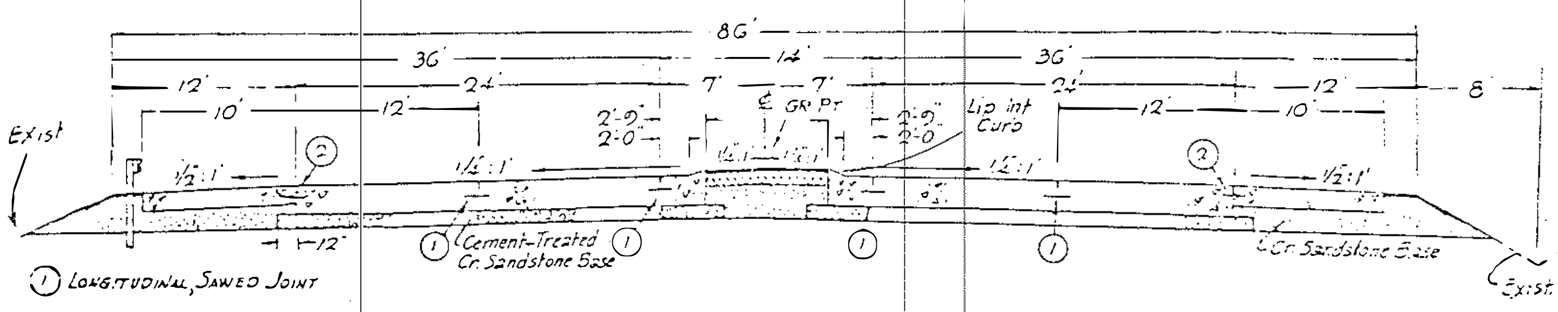
Pavement — [13" Surface — [Standard Reinforced P.C.C. Pavement
-OR-
Non-Reinforced P.C.C. Pavement

Median — [Approx. 16" — [11"± Compacted Depth Crushed Sandstone Base - Spec. Prov. No. 40 (76)
Compacted Depth Bituminous Concrete Base, Class S - Spec. Prov. No. 42 (76)
4"± Compacted Depth Bituminous Concrete Base (2 - 2" Courses)
1"± Compacted Depth Bituminous Concrete Surface

Shoulder — [Paved Approx. 13" — [5"± Compacted Depth Crushed Sandstone Base - Spec. Prov. No. 40 (76)
- WITH -
8" Standard Reinforced P.C.C. Pavement
-OR-
8" Non-Reinforced P.C.C. Pavement

PORTLAND CEMENT CONCRETE ON CEMENT-TREATED SANDSTONE BASE

STA. 3328+00 To STA. 3929+00



(1) LONGITUDINAL, SAWED JOINT

(2) LONGITUDINAL, SAWED CONST. JOINT

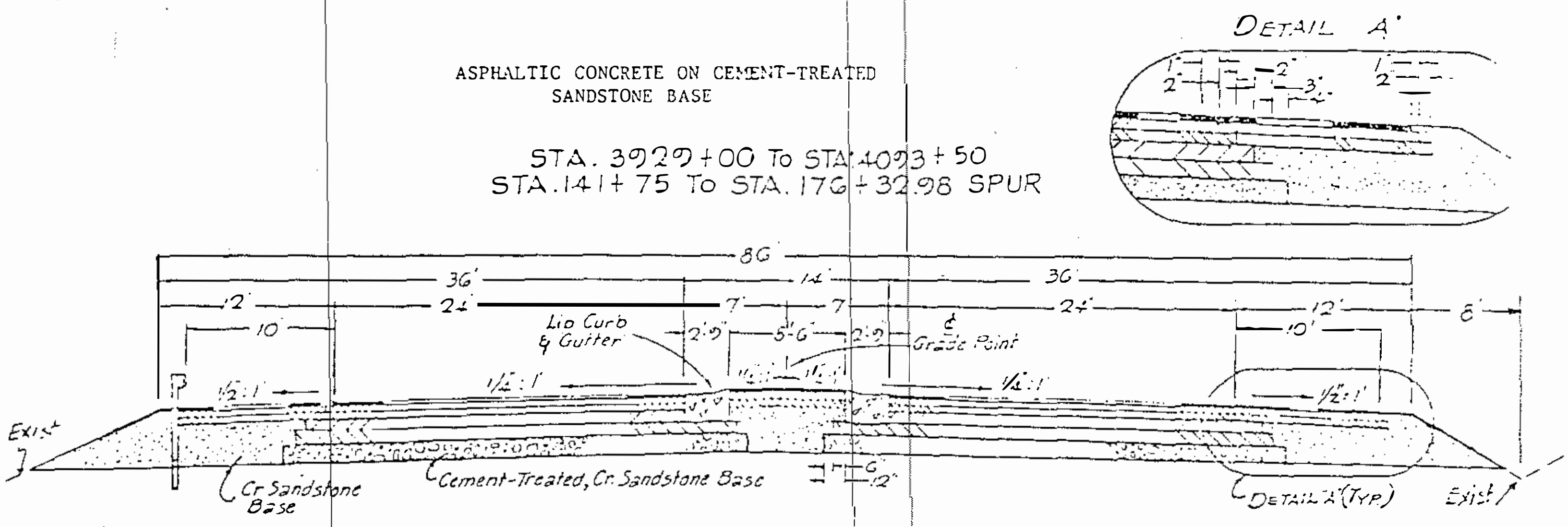
Approx. 17" Pavement
- Approx. 6" Base — 6"± Compacted Crushed Sandstone Base, Plant Mixed-Cement Treated-Spec. Prov. No. 4[illegible](76)
  - WITH -
- Approx. 11" Surface — Standard Reinforced P.C.C. Pavement
  - OR -
  Non-Reinforced P.C.C. Pavement

Median — Approx. 20" —
- 15"± Compacted Depth Crushed Sandstone Base - Spec. Prov. No. 40(76)
- Compacted Depth Bituminous Concrete Base, Class S - Spec. Prov. No. 42(76)
- 4"± Compacted Depth Bituminous Concrete Base (2-2" Courses)
- 1"± Compacted Depth Bituminous Concrete Surface

Shoulder — Paved Approx. 17" —
- 9"± Compacted Depth Crushed Sandstone Base - Spec. Prov. No. 40(76)
  - WITH -
- 8" Standard Reinforced P.C.C. Pavement
  - OR -
- 8" Non-Reinforced P.C.C. Pavement

ASPHALTIC CONCRETE ON CEMENT-TREATED SANDSTONE BASE

STA. 3929+00 To STA. 4093+50
STA. 141+75 To STA. 176+32.98 SPUR

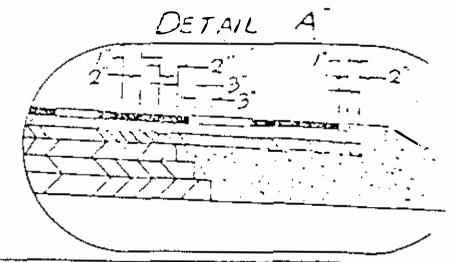


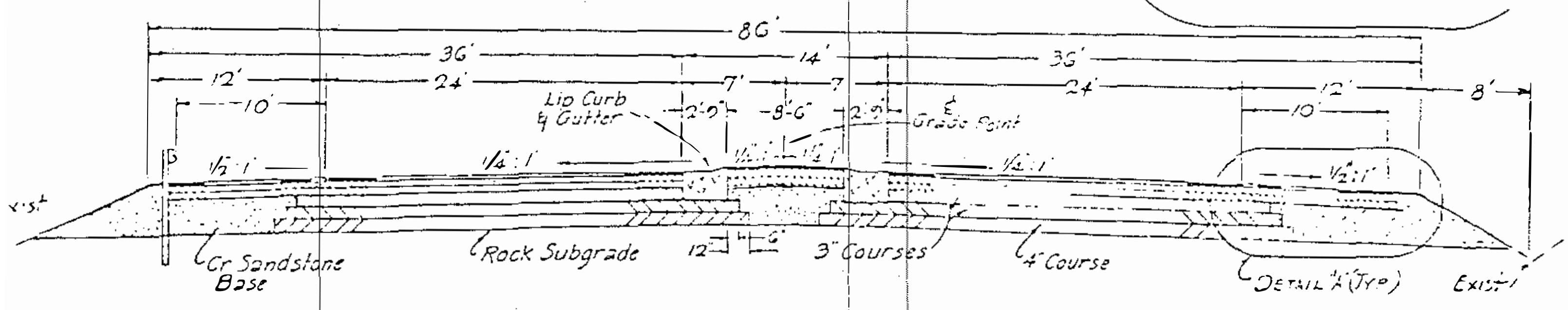
- Approx. 18" Pavement
  - Approx. 17" Base
    - 6" ± Compacted Depth Crushed Sandstone Base - Cement Treated - Spec. Prov. No. 41 (76)
    - 7" ± Compacted Depth Bituminous Concrete Base - Class S (4" and 3" courses) - Spec. Prov. No. 42 (76)
    - 4" ± Compacted Depth Bituminous Concrete Base (2 - 2" courses)
  - Tack Coat — 0.8 Lbs per sq. yd Apply as directed.
  - Surface — 1" ± Compacted Depth Bituminous Concrete Surface

- Paved
  - Median - Approx. 21"
  - Shoulders - Approx. 18"
    - Full Depth Compacted Crushed Sandstone Base - Spec. Prov. No. 40 (76)
    - Bituminous Concrete Base - Class S Spec. Prov. No. 42 (76)
    - 4" ± Compacted Depth Bituminous Concrete Base (2 - 2" courses)
    - 0.8 Lbs per sq. yd Tack Coat Apply as directed.
    - 1" ± Compacted Depth Bituminous Concrete Surface

FULL-DEPTH ASPHALTIC CONCRETE

STA. 4093 + 50 To STA. 4835 + 46





Approx. 13" Pavement (12" from Sta. 4715 + 00)

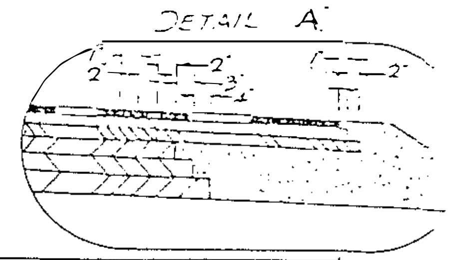
- Approx 12" Base
  - 10" ± Compacted Depth Bituminous Concrete Base - Class S (1-4" & 2-3 courses) Spec. Prov. No 42(76)
  - 2" ± Compacted Depth Bituminous Concrete Base (1 - 2" courses)
- Tack Coat — 0.8 Lbs. per sq. yd. Apply as directed.
- Surface — 1" ± Compacted Depth Bituminous Concrete Surface

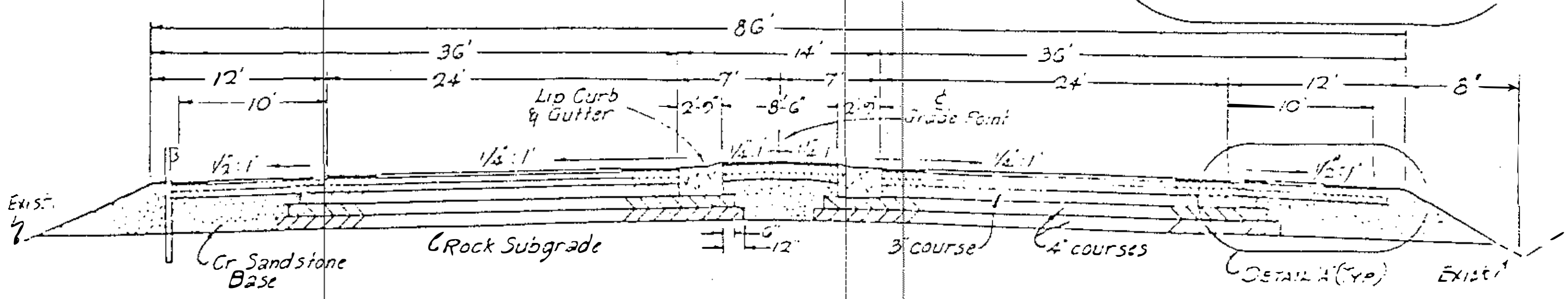
Paved

- Median-Approx. 16" (15" from Sta. 4715+00)
- Shoulders-Approx. 13" (12" from Sta. 4715+00)
  - Full Depth Compacted Crushed Sandstone Base - Spec. Prov. No 40 (76)
  - Compacted Depth Bituminous Concrete Base - Class S Spec. Prov. No. 42 (76)
  - 4" ± Compacted Depth Bituminous Concrete Base (2 - 2" courses)
  - 0.8 Lbs. per sq. yd. Tack Coat Apply as directed.
  - 1" ± Compacted Depth Bituminous Concrete Surface

FULL-DEPTH ASPHALTIC CONCRETE

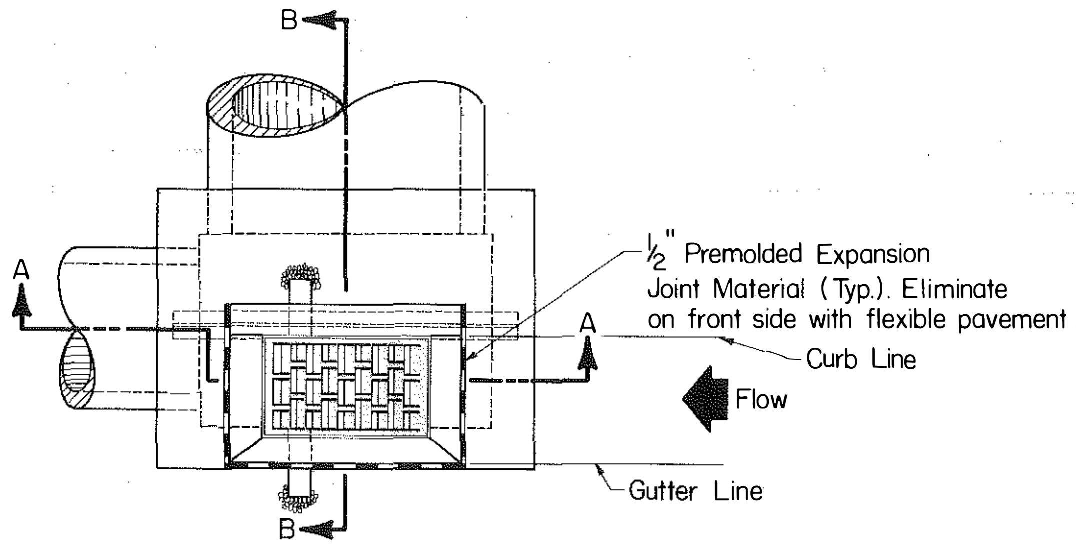
STA. 4835+46 To STA. 4977+79 BK= STA. 812+16 Ah.





Approx. 14" Pavement
- Approx. 13" Base
  - 11" ± Compacted Depth Bituminous Concrete Base - Class S (2-4" & 1-3" course) Spec. Prov. No. 42 (76)
  - 2" ± Compacted Depth Bituminous Concrete Base (1-2" course)
- Tack Coat — 0.8 Lbs. per sq. yd. Apply as directed.
- Surface — 1" ± Compacted Depth Bituminous Concrete Surface

Paved
- Median-Approx. 17"
- Shoulders-Approx. 14"
  - Full Depth Compacted Crushed Sandstone Base - Spec. Prov. No. 40 (76)
  - 3" ± Compacted Depth Bituminous Concrete Base - Class S - Spec. Prov. No. 42 (76)
  - 4" ± Compacted Depth Bituminous Concrete Base (2-2" courses)
  - 0.8 Lbs. per sq. yd. Tack Coat. Apply as directed.
  - 1" ± Compacted Depth Bituminous Concrete Surface



PLAN VIEW

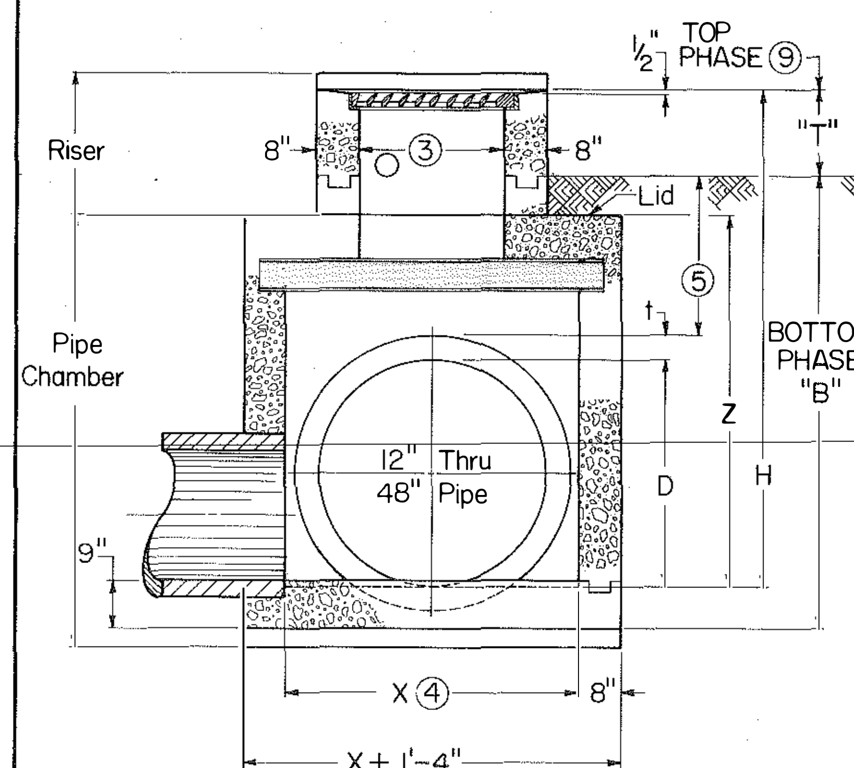
NOTES

1. Box Inlet shall be constructed in two phases (Bottom and Top) and may be constructed in a sag vertical curve or on grade.

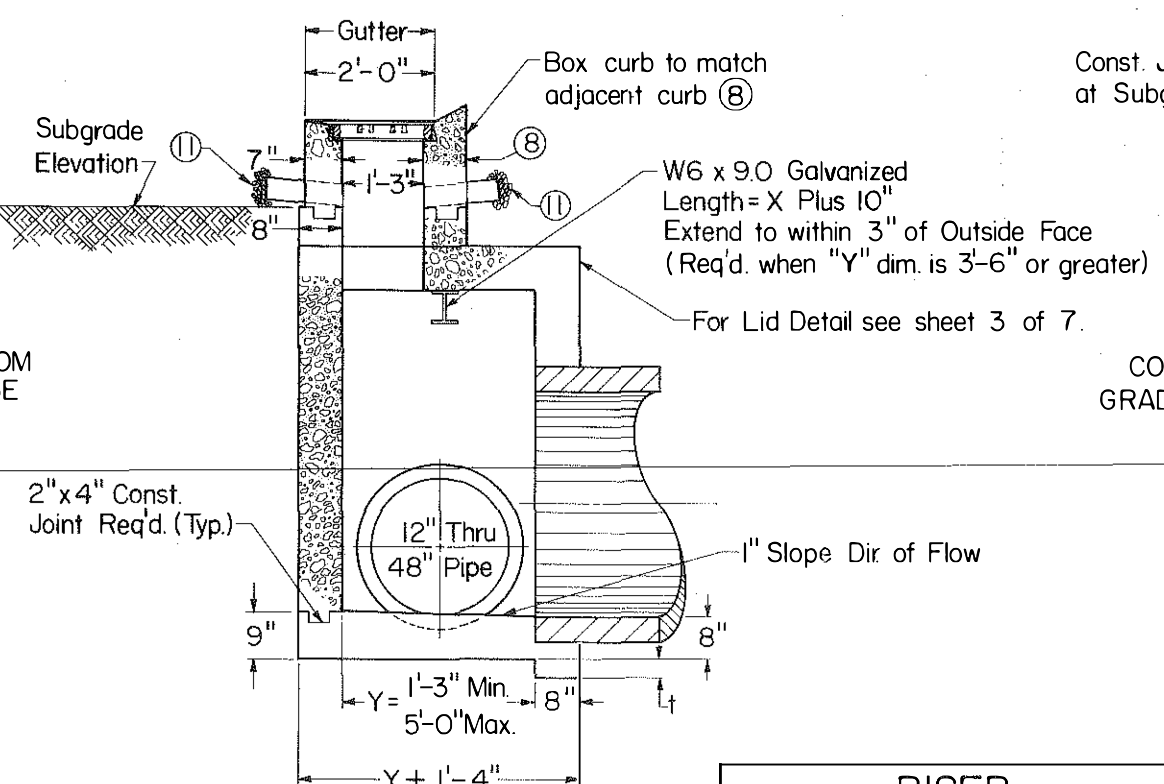
   Bid Item: Drop Box Inlet Type 13 (▲) (∗)
   (▲) = "S" (Sag Condition)
   (▲) = "G" (Grade Condition)
   (∗) = "T" (Top Phase)
   (∗) = "B" (Bottom Phase)

   With no "T" or "B" suffix a complete inlet is required.

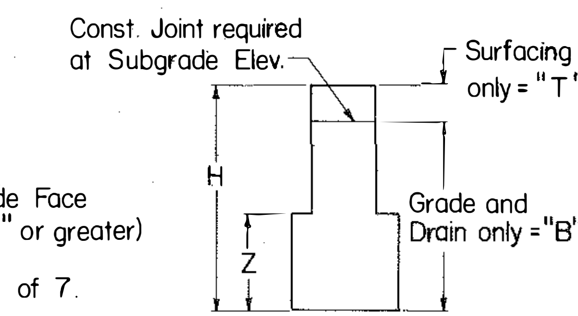
2. For illustration purposes this drawing depicts a box located on a grade condition. See Sheet 2 of 7 for details of sag and grade conditions.
3. (3) Dimension varies depending upon location of box: Grade condition = 2'-3", Sag condition = 4'-11".
4. (4) Grade Condition: X = 2'-3" min. to 5'-0" max., Sag Condition: X = 4'-11".
5. (5) 24" desired cover, 12" minimum cover over pipe and/or lid.
6. "t" is concrete pipe wall thickness or metal corrugation depth.
7. All walls and slabs are 8" thick unless otherwise shown.
8. (8) Thickness = Curb width + 2" (minimum width 8" without curb). Inlet may be constructed with or without a curb. The curb on the box shall be constructed to match the adjoining curb with the same construction and material details (See current Std. Dwg. RPM-100). This drawing depicts a lip curb application.
9. (9) The top phase shall be cast after the adjoining curb and gutter have been cast.
10. See Sheets 2, 3, 4, 5, 6 and 7 of 7 for Frame and Grade Detail, Steel Pattern, Dimensions and Quantities.
11. (11) Spalls or crushed stone around end of 4" or 6" pipe for Subgrade Drainage.



SECTION A-A



SECTION B-B



CONSTRUCTION SEQUENCE FOR GRADE & DRAIN AND/OR SURFACING

METRIC CONVERSIONS
1 FT. = 0.3048 m
1 IN. = 25.4 mm

RISER	
CU. YD. CONC. PER FT. HT.	
SAG	0.4
GRADE	0.2

Sheet 1 of 7

KENTUCKY BUREAU OF HIGHWAYS

DROP BOX INLET TYPE 13 (DETAIL SHEET)

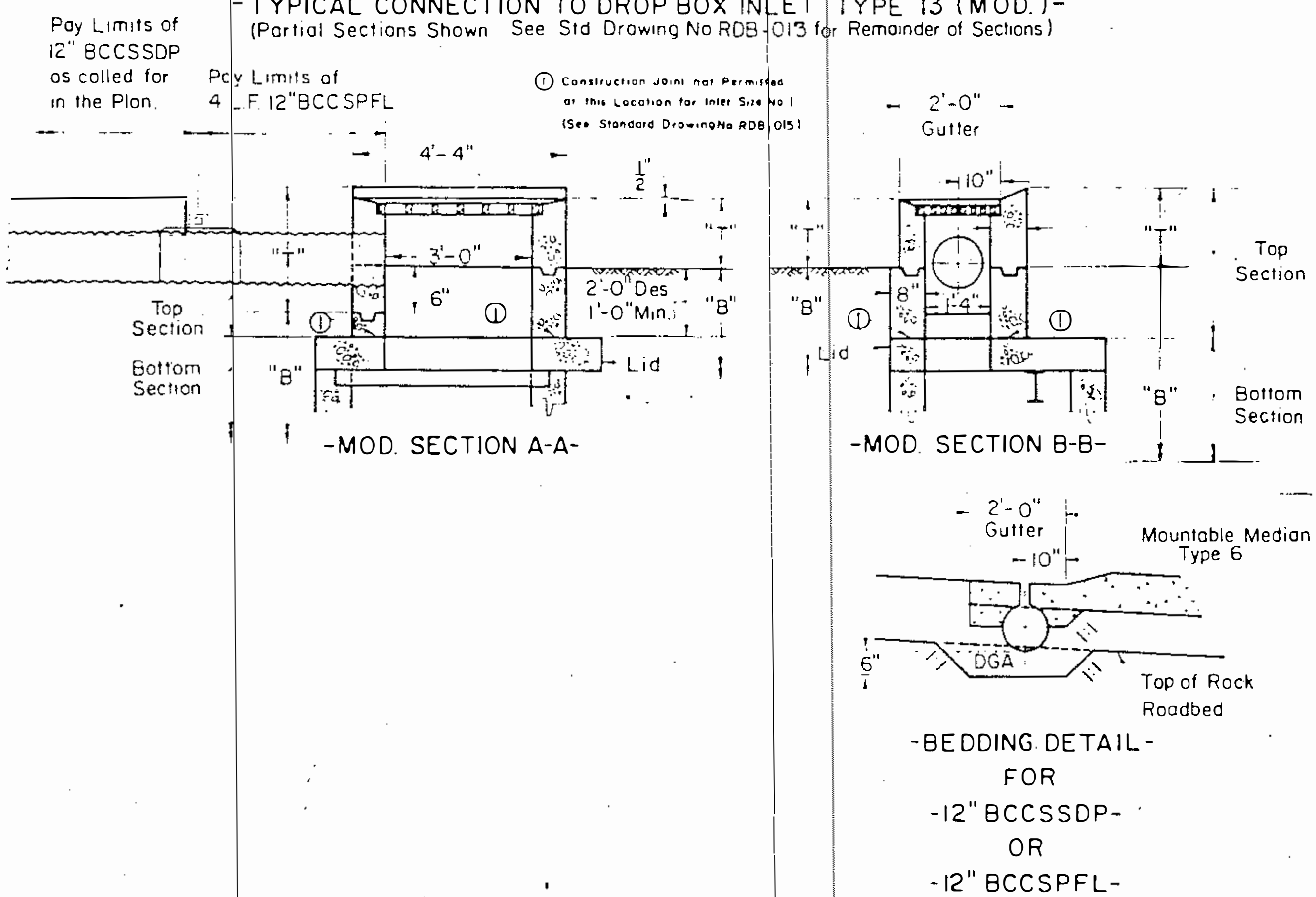
STANDARD DRAWING No.
SUBMITTED E.B. Drake, Asst. DIRECTOR DIVISION OF DESIGN — DATE 8/27/82
APPROVED ____ STATE HIGHWAY ENGINEER — DATE

DIETZGEN DATE 9-1-81 FORM NO. 10

DRAWN ____ DATE 8/27/82
CHECKED ____ 8-27-82
RECOMMENDED ____
APPROVED FHWA ____

-TYPICAL CONNECTION TO DROP BOX INLET TYPE 13 (MOD.)-

(Partial Sections Shown See Std Drawing No RDB-013 for Remainder of Sections)



APPENDIX B

BITUMINOUS CONCRETE THICKNESS REPORT

AND

DENSITY OF BITUMINOUS CONCRETE CORES

923

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF TRANSPORTATION
FRANKFORT, KENTUCKY 40622

FRANK R. METTS
SECRETARY

JOHN Y. BROWN, JR.
GOVERNOR

December 4, 1981

Mr. Michael Rudloff
Chief Engineer
Brighton Engineering Company
Brighton Park, P.O. Box 558
Frankfort, Kentucky 40602

Dear Mr. Rudloff :

Subject: Bituminous Concrete Thickness Report
For Knott County; KY RR 80-423,
SSP 060-0080-007-014-048-C (850)

Attached is a Bituminous Concrete Thickness Report for the subject project. This report shows the individual measurements for both the Limestone and Sandstone base courses. Also attached is a summary showing the sections found to be outside the thickness tolerances. This summary shows both the amount of deductions based on the measured thicknesses and the amount of deductions after adjustment for the allowance of ten percent additional material as a construction tolerance on rock roadbed.

Please, contact this office if you have any questions or need additional information concerning this report.

Sincerely,

DIVISION OF MATERIALS

John E. McChord, Director

By: Dwight Walker
Civil Engineer

JEM:DW:vjs
Attachments
cc: Bennie Wheat
Project File

DIVISION OF MATERIALS
BITUMINOUS PAVEMENT THICKNESS
INTER-OFFICE REPORT

COUNTY KNOTT PROJECT KY RR 80-123; SSP 60-30-637-61 [illegible]

CORE NO.	STATION NO.	DISTANCE FROM C/L	PAVEMENT DEPTH	REMARKS
	4089+00 Begin West Bound Lane			
W1	4093+18	7' RT	11.80	
W2A	4101+18	6' LT	12.30	
W2	4103+18	8' LT	13.10	+ 0.60"
W2B	4105+18	5' LT	12.50	
W3A	4111+19	2' RT	12.40	
W3	4113+19	4' RT	13.00	+ 0.50"
W3B	4115+19	6' RT	13.80	+ 1.30"
~~W3C~~	~~4117+19~~	~~9' RT~~	~~13.80~~	~~+ 1.30"~~
W3D	4119+19	C/L	13.20	+ 0.70"
W3E	4121+19	6' LT	12.90	+ 0.40"
THIS AREA WILL NOT BE DRILLED DUE TO IRREGULAR DEPTH OF BITUMINOUS BASE IN SLIDE AREA				
W5A	4131+21	4' RT	13.30	+ 0.80"
W5	4133+21	7' RT	13.30	+ 0.80"
W5E	4135+21	4' RT	13.30	+ 0.80"
W5F	4137+21	1' RT	12.80	+ 0.30"
W5G	4139+21	2' LT	13.50	+ 1.00"
W5H	4141+21	4' LT	11.50	
W6	4143+25	7' LT	12.70	+ 0.20"
W6A	4145+25	5' LT	12.30	
W7	4153+24	3' RT	12.30	
W8A	4161+26	3' LT	12.40	
W8	4163+26	4' LT	13.00	+ 0.50"
W8B	4165+26	2' LT	12.50	
~~W9~~	~~4173+10~~	~~6' RT~~	~~12.20~~	
W10	4183+13	7' LT	11.50	
W11	4193+08	7' RT	12.30	
W12B	4199+04	1' RT	12.00	
W12A	4201+04	2' LT	11.10	- 0.90"
W12	4203+04	5' LT	10.80	- 1.20"
W12C	4205+04	1' LT	13.10	+ 0.60"
W12D	4207+04	2' RT	12.80	+ 0.30"
W12E	4209+04	6' RT	12.40	
W13A	4211+40	6' RT	13.60	+ 1.10"
W13	4213+40	9' RT	10.70	- 1.30"
[illegible]	4215+40	4' RT	12.40	
W14A	4221+02	5' LT	12.10	
W14	4223+02	8' LT	13.40	+ 0.90"
W14B	4225+02	3' LT	13.00	+ 0.50"
W14C	4227+02	C/L	12.30	
W15B	4229+26	1' LT	11.50	
W15A	4231+26	2' RT	13.20	+ 0.70"

CORE NO.	STATION NO.	DISTANCE FROM C/L	PAVEMENT DEPTH	REMARKS
	4089+00 Begin East Bound Lane			
E1	4093+78	6' LT	11.90	
E2	4103+45	3' RT	11.70	
E3	4113+28	10' LT	12.00	
THIS AREA WILL NOT BE DRILLED DUE TO IRREGULAR BITUMINOUS BASE DEPTH AT SLIDE AREA.				
E5A	4131+45	8' LT	11.60	
E5	4133+45	10' RT	11.00	- 1.00"
E5E	4135+45	7' LT	11.70	
E6	4143+78	C/L	11.50	
E7B	4149+53	4' LT	11.70	
E7A	4151+53	7' LT	10.60	- 1.40"
E7	4153+53	10' LT	11.40	- 0.60"
E7C	4155+53	7' LT	11.10	- 0.90"
E7D	4157+53	4' LT	11.10	- 0.90"
E7E	4159+53	2' LT	11.80	
E8A	4161+75	C/L	11.60	
E8	4163+72	3' RT	12.80	+ 0.50"
E8B	4165+75	1' RT	12.50	
E9	4173+60	8' LT	11.80	
E10B	4179+36	5' RT	12.10	
E10A	4181+36	7' RT	10.00	- 2.00"
E10	4183+36	10' RT	10.70	- 1.30"
E10C	4185+36	7' RT	12.10	
E11A	4191+20	3' LT	11.70	
E11	4193+20	6' LT	10.80	- 1.20"
E11B	4195+20	4' LT	11.90	
E12	4203+25	5' RT	12.50	
E13	4213+67	4' LT	12.40	
E14	4223+13	6' RT	12.20	
E15	4233+55	9' LT	11.70	
E16	4243+80	9' RT	12.50	
E17B	4249+21	C/L	12.00	
E17A	4251+21	3' LT	11.30	- 0.70"
E17	4253+21	5' LT	13.00	+ 0.50"
E17C	4255+21	2' LT	13.00	+ 0.50"
E17D	4257+21	2' RT	13.10	+ 0.30"
E17E	4259+21	5' RT	10.70	- 1.30"
E17F	4261+21	7' RT	11.00	- 1.00"
E18	4263+75	10' RT	10.70	- 1.30"
E18A	4265+75	7' RT	10.70	- 1.30"
E18B	4267+75	4' RT	10.70	- 1.30"
E18C	4269+75	C/L	11.80	

DIVISION OF MATERIALS
BITUMINOUS PAVEMENT THICKNESS
INTER-OFFICE REPORT

COUNTY KNOTT PROJECT KY RR 80-423; SSP 60-30-007-01 [illegible]

CORE NO.	STATION NO.	DISTANCE FROM C/L	PAVEMENT DEPTH	REMARKS	CORE NO.	STATION NO.	DISTANCE FROM C/L	PAVEMENT DEPTH	REMARKS
	West Bound Lane (cont'd)					East Bound Lane (cont'd)			
W15	4233+26	4' RT	13.10	+ 0.60"	E19A	4271+63	3' LT	12.50	
W15C	4235+26	2' RT	12.40		E19	4273+63	6' LT	10.30	- 1.20"
W16B	4239+46	C/L	12.40		E19B	4275+63	3' LT	11.60	
W16A	4241+46	1' LT	13.00	+ 0.50"					
W16	4243+46	3' LT	12.80	+ 0.30"					
W16C	4245+46	1' LT	12.30		E20A	4281+04	3' RT	12.00	
W17	4253+14	6' RT	12.10		E20	4283+04	7' RT	12.60	- 1.10"
W18	4253+13	6' LT	12.30		E20B	4285+04	5' RT	11.70	
W19	4273+37	9' RT	12.40		E21B	4239+34	1' RT	11.80	
W20A	4281+31	5' LT	11.50		E21A	4291+34	2' LT	13.10	+ 0.60"
W20	4283+31	9' LT	10.90	- 1.10"	E21	4293+34	4' LT	13.30	+ 0.80"
W20B	4235+31	5' LT	11.10	- 0.90"	E21C	4295+34	2' LT	12.40	
W20C	4237+31	1' LT	11.50		E22	4303+21	6' RT	11.30	
W21A	4291+17	2' RT	12.50		E23	4313+55	5' LT	11.60	
W21	4293+17	5' RT	10.00	- 2.00"	E24A	4321+58	3' RT	11.50	
W21B	4295+17	2' RT	11.70		E24	4323+58	9' RT	11.30	- 0.70"
					E24B	4325+58	6' RT	11.80	
					E25	4333+73	7' LT	12.30	
W22	4303+00	6' LT	11.90		E26A	4341+18	6' RT	11.70	
W23D	4305+33	4' LT	12.00		E26	4343+18	9' RT	11.30	- 0.70"
W23C	4307+33	1' LT	10.90	- 1.10"	E26B	4345+18	6' RT	11.50	
W23B	4309+33	1' RT	10.60	- 1.40"	E27A	4351+25	5' LT	11.80	
W23A	4311+33	4' RT	11.00	- 1.00"	E27	4353+25	8' LT	11.00	- 1.00"
W23	4313+33	6' RT	11.30	- 0.70"	E27B	4355+25	5' LT	11.30	
W23E	4315+33	3' RT	12.50		E28	4363+43	6' RT	11.90	
W24	4323+66	4' LT	12.40		E29A	4371+51	4' LT	12.30	
W25A	4331+71	6' RT	11.70		E29	4373+51	7' LT	13.20	+ 0.70"
W25	4333+71	9' RT	11.00	- 1.00"	E29B	4375+51	4' LT	11.80	
W25B	4335+71	6' RT	12.50		E30A	4381+34	2' RT	12.20	
W26	4343+21	5' LT	11.90		E30	4383+34	5' RT	13.60	+ 1.10"
W27	4353+31	5' RT	11.80		E30B	4385+34	2' RT	11.60	
W28B	4359+27	1' LT	12.40		E31A	4391+67	6' LT	12.00	
W28A	4361+27	3' LT	13.90	+ 1.40"	E31	4393+67	9' LT	11.20	- 0.80"
W28	4363+27	4' LT	13.80	+1.30"	E31B	4395+67	6' LT	12.20	
W28C	4365+27	2' LT	14.10	+ 1.60"	E32	4403+70	2' RT	12.20	
W28D	4367+27	C/L	12.40		E33	4413+16	10' LT	12.00	
W29	4373+24	8' RT	11.90		E34	4423+24	6' RT	11.90	
W30	4383+23	7' LT	12.00			4432+00 End Main Line			
W31	4393+53	5' RT	12.20						
W32A	4401+51	6' LT	11.90						
W32	4403+51	9' LT	11.30	- 0.70"					
W32B	4405+51	5' LT	12.20						
W33	4413+53	6' RT	12.00						
W34A	4421+03	1' LT	11.80						
W34	4423+03	3' LT	12.60	+ 0.10"					
W34B	4425+03	1' LT	12.50						
	4432+00 End Main Line								

DIVISION OF MATERIALS
BITUMINOUS PAVEMENT THICKNESS
INVESTIGATION REPORT

COUNTY KNOTT PROJECT KY RR 80-423; SSP 59-80-037-014 48 C 350

CORE NO.	STATION NO.	DISTANCE FROM C/L	PAVEMENT DEPTH	REMARKS	CORE NO.	STATION NO.	DISTANCE FROM C/L	PAVEMENT DEPTH	REMARKS
	West Bound Shoulder (4" Base) 4089+00 Begin					East Bound Shoulder (4" Base) 4089+00 Begin			
WS 1	4094+40	17' LT	4.00		ES 1	4094+88	18' RT	4.00	
WS 2	4114+52	18' LT	3.70		ES 2	4114+89	15' RT	3.80	
WS 3	4134+39	19' LT	4.10		ES 3A	4130+79	19' RT	4.20	
WS 4	4154+29	15' LT	4.40		ES 3	4134+79	17' RT	2.70	- 1.30"
WS 5	4174+07	14' LT	3.60		ES 3B	4136+79	19' RT	2.50	- 1.50"
WS 6	4194+09	19' LT	3.60		ES 3C	4138+79	15' RT	3.30	
WS 7	4214+42	14' LT	3.70		ES 4	4154+37	16' RT	4.10	
WS 8	4234+23	18' LT	4.30		ES 5	4174+66	20' RT	4.20	
WS 9	4254+33	15' LT	3.90		ES 6	4194+42	14' RT	4.00	
WS10	4274+25	19' LT	3.90		ES 7	4214+55	18' RT	4.20	
WS11A	4292+60	18' LT	3.70		ES 8A	4232+37	17' RT	3.50	
WS11	4294+60	15' LT	3.00	- 1.00"	ES 8	4234+37	19' RT	3.40	
WS11B	4296+60	18' LT	3.60		ES 8B	4236+37	16' RT	2.90	- 1.10"
WS12	4314+96	14' LT	4.10		ES 8C	4238+37	18' RT	3.70	
WS13	4334+27	18' LT	3.70		ES 9A	4252+52	20' RT	4.50	
WS14	4354+30	16' LT	4.00		ES 9	4254+52	15' RT	3.30	-0.70"
WS15	4374+13	17' LT	3.80		ES 9A	4256+52	20' RT	3.80	
WS16	4394+33	15' LT	4.40		ES 10	4274+37	14' RT	3.90	
WS17	4414+15	18' LT	4.20		ES 11	4294+27	20' RT	3.60	
WS18	4432+10	22' LT	3.50		ES 12	4314+40	14' RT	4.00	
					ES 13	4334+36	17' RT	3.60	
					ES 14	4354+15	16' RT	3.90	
					ES 15	4374+60	17' RT	4.50	
					ES 16	4394+18	14' RT	4.30	
					ES 17	4414+54	19' RT	4.10	
					ES 18	4431+90	15' RT	4.30	

INDIVIDUAL MEASUREMENTS OF LIMESTONE AND SANDSTONE
KY RR 80-423; SSP 30-80-007-01 1 46 C 033

WEST BOUND

CORE	LIMESTONE	SANDSTONE
W 1	1.50	10.30
W 2A	2.20	10.10
W 2	2.10	11.00
W 2B	2.10	10.40
W 3A	2.20	10.20
W 3	2.50	10.50
W 3B	1.80	12.00
W 3C	2.00	11.80
W 3D	2.00	11.20
W 3D	1.80	11.10

THIS AREA WILL NOT BE DRILLED DUE TO ~~IRREGULAR DEPTH OF BITUMINOUS BASE~~ IN SLIDE AREA

CORE	LIMESTONE	SANDSTONE
W 5A	1.70	11.60
W 5	2.10	11.20
W 5E	2.20	11.10
W 5F	2.40	10.40
W 5G	2.00	11.50
W 5H	1.80	9.70
W 6	1.90	10.80
W 6A	2.30	10.00
W 7	1.80	10.50
W 8A	2.80	9.60
W 8	2.40	10.60
W 8B	2.30	10.20
W 9	1.30	10.90
W10	1.80	9.70
W11	1.70	10.60
W12B	2.20	9.80
W12A	2.50	8.60
~~W12~~	~~1.90~~	~~8.90~~
W12C	2.30	10.80
W12D	2.20	10.60
W12E	1.60	10.80
W13A	1.80	11.80
W13	1.90	8.80
W13B	1.50	10.90
W14A	1.90	10.20
W14	2.20	11.20
W14B	2.10	10.90
W14C	2.60	9.70
W15B	2.20	9.30
W15A	1.70	11.50

EAST BOUND

CORE	LIMESTONE	SANDSTONE
E 1	1.60	10.30
E 2	2.10	9.60
E 3	1.90	10.20

THIS AREA WILL NOT BE DRILLED DUE TO IRREGULAR BITUMINOUS BASE DEPTH AT SLIDE AREA.

CORE	LIMESTONE	SANDSTONE
E 5A	1.30	10.30
E 5	1.50	9.50
~~E 5E~~	~~1.40~~	~~10.30~~
E 6	1.90	9.60
E 7B	1.90	9.80
E 7A	1.30	9.30
E 7	1.40	10.00
E 7C	1.20	9.90
E 7D	1.70	9.40
E 7E	2.30	9.50
E 8A	2.00	9.60
E 8	1.70	11.10
E 8B	2.30	10.20
E 9	1.40	10.40
E10B	1.80	10.30
E10A	1.40	8.60
E10	0.70	10.00
E10C	2.00	10.10
E11A	1.70	10.00
E11	1.40	9.40
E11B	1.80	10.10
E12	1.70	10.60
E13	2.70	9.70
E14	1.90	10.30
E15	1.20	10.50
E16	2.00	10.50
~~E17B~~	~~2.00~~	~~10.00~~
E17A	1.80	9.50
E17	1.90	11.10
E17C	1.20	11.80
E17D	2.00	11.10
E17E	1.80	8.90
E17F	1.40	9.60
E18	1.40	9.30
E18A	1.80	8.90
E18B	1.60	9.10
E18C	2.20	9.60

INDIVIDUAL MEASUREMENTS OF LIMESTONE AND SANDSTONE
KY RR 30-423; SSP 60-30-007-014 43 (C &)

WEST BOUND (cont'd)

CORE	LIMESTONE	SANDSTONE
W15	1.70	11.40
W15C	1.80	10.60
W15B	3.00	9.40
W16A	3.50	9.50
W16	2.50	10.30
W16C	2.80	9.50
W17	1.40	10.70
W18	1.90	10.40
W19	1.80	10.60
W20A	1.60	9.90
W20	1.80	9.10
W20B	1.90	9.20
W20C	2.40	9.10
W21A	1.50	11.00
W21	1.60	8.40
W21B		
W22	2.00	9.90
W23D	2.00	10.00
W23C	1.70	9.20
W23B	2.00	8.60
W23A	2.00	9.00
W23	2.20	9.10
W23E	2.00	10.50
W24	2.00	10.40
W25A	2.80	8.90
W25	2.50	8.50
W25B	2.60	9.90
W26	1.90	10.00
W27	2.20	9.60
W28B	2.40	10.00
W28A	2.00	11.90
W28	2.00	11.80
W28C	2.70	11.40
W28D	2.60	9.80
W29	2.20	9.70
W30	1.70	10.30
W31	2.70	9.50
W32A	2.40	9.50
W32	2.20	9.10
W32B	2.10	10.10
W33	2.10	9.90
W34A	2.60	9.20
W34	2.10	10.50
W34B	2.10	10.40

EAST BOUND (cont'd)

CORE	LIMESTONE	SANDSTONE
E19A	2.00	12.50
E19	1.40	9.40
E19B	1.10	10.50
E20A	1.60	10.40
E20	1.40	9.20
E20B	1.20	10.50
E21B	1.70	10.10
E21A	2.90	10.20
E21	1.90	11.40
E21C	1.90	10.50
E22	1.80	10.00
E23	1.40	10.20
E24A	1.40	10.10
E24	1.40	9.90
E24B	1.60	10.30
E25	1.00	11.30
E26A	1.90	9.30
E26	1.20	10.10
E26.B	1.60	9.90
E27A	2.40	9.40
E27	2.00	9.00
E27B	2.00	9.60
E28	1.20	10.70
E29A	2.00	10.30
E29	2.00	11.20
E29B	2.10	9.70
E30A	2.00	10.20
E30	2.50	11.10
E30B	2.00	9.60
E31A	2.40	9.60
E31	2.00	9.20
E31B	2.60	9.60
E32	2.00	10.20
E33	2.30	9.70
E34	1.80	10.10

Project Summary of Sections Outside Thickness Tolerances For Knott County
KY RR 80-423, SSP 060-0080-007-014-048-C

STATIONS	LINEAR FEET	EXCESS DEDUCTION (MEASURED)	EXCESS DEDUCTION (ADJUSTED)	DEFICIENT DEDUCTION
WESTBOUND LANE, 12.0 INCH BASE				
4101+68-4105+18	350	15.2	0.0	----
4111+52-4121+19	967	114.8	58.6	----
4131+21-4140+21	900	88.4	36.1	----
4142+91-4144+25	134	1.9	0.0	----
4161+59-4165+26	367	13.3	0.0	----
4200+15-4203+65	350	----	----	47.0
4204+52-4208+54	402	18.6	0.0	----
4209+24-4212+16	292	23.3	6.3	----
4212+85-4214+34	149	----	----	19.5
4221+64-4226+45	481	34.5	6.6	----
4230+43-4234+97	454	30.5	4.1	----
4239+79-4244+66	487	20.2	0.0	----
4281+31-4287+31	600	----	----	72.5
4291+97-4294+93	296	----	----	53.7
4306+13-4313+66	753	----	----	112.5
4332+28-4334+38	210	----	----	22.8
4359+40-4367+15	775	122.0	77.0	----
4402+84-4403+95	111	----	----	9.7
4422+78-4425+03	225	1.6	0.0	----
EASTBOUND MAINLINE, 12.0 INCH BASE				
4131+78-4134+88	310	----	----	33.6
4149+89-4158+67	878	----	----	111.0
4163+23-4165+75	252	5.5	0.0	----
4179+93-4184+50	457	----	----	88.6

STATIONS	LINEAR FEET	EXCESS DEDUCTION (MEASURED)	EXCESS DEDUCTION (ADJUSTED)	DEFICIENT DEDUCTION
EASTBOUND MAINLINE, 12.0 INCH BASE				
4191+64-4194+47	283	----	----	34.8
4250+64-4251+45	81	----	----	7.0
4252+62-4257+71	509	34.8	5.2	----
4258+54-4269+20	1066	----	----	178.7
4272+81-4275+38	257	----	----	31.7
4281+75-4284+67	292	----	----	40.2
4290+42-4295+12	470	34.6	7.3	----
4321+58-4324+38	280	----	----	24.4
4342+18-4345+18	300	----	----	26.1
4352+00-4354+92	292	----	----	31.7
4371+95-4374+51	256	13.0	0.0	----
4381+77-4384+44	267	21.3	5.8	----
4392+92-4394+27	135	----	----	12.7
WESTBOUND SHOULDER, 4.0 INCH BASE				
4293+17-4296+27	310	----	----	13.8
EASTBOUND SHOULDER, 4.0 INCH BASE				
4132+66-4138+61	595	----	----	38.9
4232+37-4238+37	600	----	----	23.8
4254+19-4255+32	113	----	----	4.0

TOTAL DEDUCTIONS

EXCESS TONNAGE - 207.0

DEFICIENT TONNAGE - 1038.7

Lee Holbrook

M E M O R A N D U M

TO: Lee Holbrook
District Materials Engineer
District #10, Jackson

FROM: John E. McChord
Director
Division of Materials

BY: Dwight Walker D. W.

DATE: February 2, 1982

SUBJECT: Density of Bituminous Concrete Cores
County: Knott
Project No.: KY RR 80-423

Attached is a list showing the densities of various bituminous cores taken from the pavement of the subject project. The cores tested were those taken for thickness requirement. Those cores which were not damaged or distorted during hauling and handling were checked.

The results listed here are for your information. Please contact this office if additional information or clarification is needed concerning this report.

JEM:DW:vjs
Attachment

cc: Art Peel
Project File

DENSITY OF BITUMINOUS CORES

COUNTY: Knott TARGET DENSITY = 152.2 pcf (limestone) 140.0 pcf (sandstone)

PROJECT NUMBER: KY RR 80-423; SSP 060-0080-007-014-048-C (850)

CORE NUMBER	STATION NUMBER	MEASURED DENSITY	MARSHALL PERCENT	REMARKS
1	4093+78	145.0	95.3	Limestone East Bound M/L
3	4113+28	143.7	94.4	"
5	4133+45	145.2	95.4	"
6	4143+78	142.2	93.4	"
7	4153+53	141.2	92.8	"
8	4163+72	144.8	95.1	"
10	4183+36	143.9	94.5	"
11	4193+20	142.8	93.8	"
12	4203+25	145.3	95.5	"
13	4213+67	144.9	95.2	"
14	4223+18	144.6	95.0	"
15	4233+55	142.1	93.3	"
16	4243+80	146.4	96.2	"
17	4253+21	147.8	97.1	"
18	4263+75	148.5	97.6	"
19	4273+63	150.3	98.8	"
20	4283+04	145.0	95.3	"
21	4293+34	149.3	98.1	"
22	4303+21	150.1	98.6	"
23	4313+55	141.5	93.0	"
24	4323+58	146.7	96.4	"
25	4333+73	140.6	92.4	"
26	4343+18	149.9	98.5	"
27	4353+25	147.3	96.8	"
28	4363+48	142.3	93.5	"
29	4373+51	143.3	94.2	"
31	4393+67	145.7	95.7	"
32	4403+70	145.9	95.9	"
1	4093+18	141.6	93.0	Limestone West Bound M/L
2	4103+18	148.8	97.8	"
				"
5	4133+21	142.6	93.7	"
7	4153+24	143.5	94.3	"
8	4163+26	145.7	95.7	"
9	4173+10	138.2	90.8	"
12	4203+04	145.8	95.8	"
14	4223+02	147.6	97.0	"
15	4233+26	142.8	93.8	"
16	4243+46	145.9	95.9	"
17	4253+14	143.4	94.2	"
19	4273+37	144.9	95.2	"
20	4283+31	145.9	95.9	"
22	4303+00	140.1	92.0	"

DENSITY OF BITUMINOUS CORES

COUNTY: Knott

TARGET DENSITY = 152.2 pcf (limestone) 140.0 pcf (sandstone)

PROJECT NUMBER: KY RR 80-423; SSP 060-0080-007-014-048-C (850)

CORE NUMBER	STATION NUMBER	MEASURED DENSITY	MARSHALL PERCENT	REMARKS
23	4313+33	148.9	97.8	West Bound-L'stone
~~25~~	~~4333+71~~	~~140.5~~	~~92.3~~	"
26	4343+21	141.9	93.2	"
27	4353+31	143.8	94.5	"
~~28~~	~~4363+27~~	~~146.1~~	~~96.0~~	"
29	4373+24	147.9	97.2	"
30	4383+28	140.6	92.4	"
31	4393+58	143.8	94.5	"
32	4403+51	145.8	95.8	"
33	4413_53	142.6	93.7	"
34	4423+03	127.9	84.0	"
				Sandstone
1	4093+78	140.3	100.2	East Bound M/L
3	4113+28	139.9	99.9	"
5	4133+45	138.2	98.7	"
6	4143+78	135.9	97.0	"
7	4153+53	136.1	97.2	"
8	4163+72	139.4	99.6	"
10	4183+36	138.0	98.6	"
11	4193+20	137.2	98.0	"
12	4203+25	138.6	99.0	"
13	4213+67	139.5	99.6	"
14	4223+18	138.7	99.1	"
15	4233+15	140.0	100.0	"
16	4243+80	137.7	98.4	"
17	4253+21	140.6	100.4	"
~~18~~	~~4263+75~~	~~141.3~~	~~100.9~~	"
19	4273+63	140.3	100.2	"
20	4283+04	137.8	98.4	"
21	4293+34	139.7	99.8	"
22	4303+21	138.6	99.0	"
23	4313+55	139.5	99.6	"
24	4323+58	138.6	99.0	"
25	4333+73	136.8	97.7	"
26	4343+18	138.1	98.6	"
27	4353+25	138.7	99.1	"
28	4363+48	140.2	100.1	"
29	4373+51	139.6	99.7	"
31	4393+67	140.4	100.3	"
32	4403+70	142.5	101.8	"
				Limestone
11	4294+60	138.5	98.9	West Bound Shoulder
12	4314+96	139.4	99.6	"
14	4354+30	138.8	99.1	"

DENSITY OF BITUMINOUS CORES

COUNTY: Knott TARGET DENSITY = 152.2 pcf (limestone) 140.0 pcf (sandstone)

PROJECT NUMBER: KY RR 80-423; SSP 060-0080-007-014-048-C (850)

CORE NUMBER	STATION NUMBER	MEASURED DENSITY	MARSHALL PERCENT	REMARKS
				Limestone
15	4374+18	137.8	98.4	West Bound Shoulder
16	4394+33	137.2	98.0	"
17.	4414+15	139.8	99.9	"
18	4432+10	138.8	99.1	"
				Limestone
11	4294+27	140.0	100.0	East Bound Shoulder
12	4314+40	137.7	98.4	"
14	4334+36	141.3	100.9	"
15	4374+60	136.6	97.6	"
16	4394+18	134.7	96.2	"
17	4414+54	139.8	99.9	"
18	4431+90	139.1	99.4	"
				Sandstone
1	4093+18	139.9	99.9	West Bound M/L
2	4103+18	136.5	97.5	"
5	4133+21	137.9	98.5	"
7	4153+24	137.8	98.4	"
8	4163+26	136.7	97.6	"
9	4173+10	139.1	99.4	"
12	4203+04	137.4	98.1	"
13	4213+40	135.7	96.9	"
14	4223+02	139.1	99.4	"
15	4223+26	138.0	98.6	"
16	4243+46	136.1	97.2	"
17	4253+14	138.3	98.8	"
19	4273+37	118.1	84.4	"
20	4283+31	137.6	98.3	"
22	4303+00	133.9	95.6	"
23	4313+33	125.1	89.4	"
24	4323+66	118.8	84.9	"
25	4333+71	141.2	100.9	"
26	4343+21	141.0	100.7	"
27	4353+31	140.4	100.3	"
28	4363+27	141.5	101.1	"
29	4373+24	138.9	99.2	"
30	4383+28	138.4	98.9	"
31	4393+58	125.7	89.8	"
32	4403+51	125.8	89.9	"
33	4413+53	125.2	89.4	"
34	4423+03	140.2	100.1	"

Average Density (limestone) = 94.9%
Average Density (sandstone) = 98.1%