Research Report
KTC-04-02/SPR 257-03-1F

KENTUCKY TRANSPORTATION CENTER

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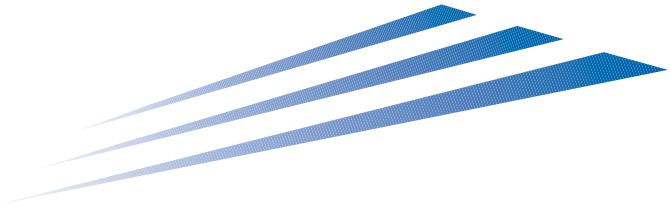
EFFECT OF PAVEMENT RESURFACING ON TRAFFIC SAFETY



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EFFECT OF PAVEMENT RESURFACING ON TRAFFIC SAFETY

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EXECUTIVE SUMMARY

The objectives of this study were to analyze the before and after crash history and speeds on routes which have been resurfaced , inspect resurfacing projects, make recommendations to improve the resurfacing process, and determine improvements which could be made in conjunction with the resurfacing project to improve the overall safety of the roadway.

An analysis of the before and after crash data did not show a reduction in total crashes after resurfacing. There was a reduction in crashes which occurred on a wet pavement. A comparison of speeds before and after resurfacing did not find a major change in travel speeds. Considering all locations, there was an average increase in speeds after resurfacing of less than one mph.

Discussion with state inspectors and contractors found agreement of areas which could be changed to improve the resurfacing process. Most of the comments dealt with preparation of the road prior to paving, methods to place the shoulder, and the paving operation.

Recommendations were made to be taken into consideration when resurfacing roads. They were grouped into the following categories: preparation for resurfacing, shoulder-related issues, paving operation, and general issues. Examples of the recommendations are as follows: 1) consider adding ditching and shouldering as part of preparation for resurfacing especially when the resurfacing extends to the ditch fore slope, 2) place a note on the typical section that the shoulder wedge should be sloped down to the adjacent turf at no more than a 45 degree angle, 3) ensure that an adequate amount of leveling material is included in the contract, 4) encourage use of non-typical additions to the contract to minimize any potential problems after resurfacing (for example, place object markers when there is a potential hazard such as a culvert headwall adjacent to the pavement), and 5) consider development of a more comprehensive policy for resurfacing that focuses both on the paved travel lanes and the adjacent roadside (shoulder, ditch, clear zone).

ACKNOWLEDGMENTS

An expression of appreciation is extended to the following members of the Study Advisory Committee from the Kentucky Transportation Cabinet for their involvement towards the success of this project.

Dexter Newman	Division of Construction, Committee Chairman
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Larry Kerr	KYTC, District 8
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1.0 INTRODUCTION

1.1 Background

Hundreds of miles of various types of roads are resurfaced each year in Kentucky. These projects typically consist of placing an overlay on the existing surface. A review of Board of Claims cases filed against the Kentucky Transportation Cabinet (KYTC) (1) has identified issues concerning either a possible shoulder dropoff or a problem with the pavement cross slope which occurred after a resurfacing project. Also, a review of fatal crashes on two-lane rural roads identified several countermeasures which could be addressed as part of the resurfacing program (2). Some of the low-cost items identified which have not been part of a typical resurfacing project were: installation of object markers/delineation at headwalls and bridge ends within the clear zone and providing additional delineation and warning for sharp horizontal curves.

1.2 Research Study Objectives

The objectives of this study were to analyze the before and after crash history and speeds on routes which have been resurfaced, inspect resurfacing projects, make recommendations to improve the resurfacing process, and determine improvements which could be made in conjunction with the resurfacing project to improve the overall safety of the roadway.

2.0 PROCEDURE

2.1 Review of Literature

A review was made of the most recent research which dealt with evaluating the effect of resurfacing on traffic safety.

2.2 Case Study Site Selection

Lists of the projects included in the resurfacing program of the Kentucky Transportation Cabinet (KYTC) was obtained for the years of 1998 through 2003. These lists were used to select locations to obtain before and after crash and speed data and conduct inspections.

2.3 Before and After Crash Analysis

A before and after crash analysis was conducted for projects where several years of before and after crash data were available. Resurfacing projects completed in 1998 and 1999 were used since three years of data were available both before and after the year of resurfacing. Data were obtained for all projects which had a minimum length of five miles. A control section was selected for each project. The control section was either adjacent to the resurfacing project or on a road in the county with similar characteristics.

The following crash data were obtained for each section.

- total crashes
- crashes on wet pavement
- fatal crashes
- injury crashes
- crashes during darkness
- single vehicle crashes
- crashes at intersections

Police reports for any fatal crash which occurred at the resurfacing locations in the three years after resurfacing were obtained. These reports were reviewed to determine if the condition of the roadway may have contributed to the crash.

2.4 Crashes with Shoulder Contributing Factor on Crash Report

The crash report has contributing factors listed for various areas. One of these general areas involve environmental related factors. One factor in the environmental area is "shoulders defective/drop-off." This factor was listed based on the opinion of the investigating police officer and may or may not have actually been a causal factor in the crash. Crashes with this code were summarized for the three years of 2000 through 2002. Copies of the fatal crash reports in which this code was listed were reviewed.

2.5 Speed Analysis

Speed data were collected before and after resurfacing on several roads which were resurfaced in 2003. The data were taken using a radar device with an attempt to obtain speeds for 100 vehicles unless the volume was very low. The sites were in rural areas with a speed limit of 55 mph. Data collection sites were selected so that roadway geometrics did not limit travel speeds to less than a typical speed on the road.

2.6 Inspection of Resurfacing Projects

Contacts were made with several KYTC district offices to determine when the work on some of the roads scheduled for resurfacing in 2003 would be conducted. An effort was made to inspect projects across the state with the work being performed by various contractors. The inspections were made during various phases of the resurfacing process.

2.7 Board of Claims Cases

A review has been made of Board of Claims cases involving the Transportation Cabinet for the past several years (1). A summary of cases involving issues which could be related to the resurfacing operation was made.

3.0 RESULTS

3.1 Review of Literature

The literature was reviewed to identify recent reports dealing with the effect of resurfacing on traffic safety. A 2001 report from the National Cooperative Highway Research Program (NCHRP) had the objective of determining if resurfacing coupled with minor and major safety improvements resulted in a measurable difference in crashes versus those locations that received only an overlay of asphalt (3). The effect of adding safety improvements to resurfacing work differed within and among the five states included in the study. The data analysis showed that there was not a single consistent pattern of effect (due to resurfacing) among and within the states. After resurfacing, there was an average 18 percent reduction in crashes in one state while crashes increased 25 percent in another state. Also, in one state adding safety improvements to resurfacing work did not seem to reduce crashes, while in another state, adding safety features did appear to provide an additional benefit.

A portion of a 2002 report from NCHRP dealt with the effect of resurfacing on travel speeds and crashes (4). Pavement resurfacing on rural two-lane highways resulted in a small increase in vehicle speeds. Mean and 85^{th} percentile vehicle speeds during the period two to four months after resurfacing were one mph higher than speeds at the same location before resurfacing. The effect varied substantially from site to site ranging from a decrease of four mph to an increase of seven mph. The duration of the period during which speeds increased following resurfacing was unlikely to exceed 30 months. It was also noted that resurfacing without accompanying geometric improvements may cause a small, short-term increase in crashes resulting from increased speeds, but the evidence for this effect was uncertain.

A comparison of projects in New York involving only resurfacing to those projects in which roadside and roadway safety improvements were incorporated with resurfacing found that in resurfacing only projects the safety initially declined but in projects involving additional safety improvements the safety improved (5). Another conclusion was that within the first six to seven years of pavement life, safety improves as the pavement ages. A description of the type and timing of safety work is given in an Engineering Instruction (6). Missing regulatory and warning signs were replaced before paving. Superelevation and shoulders were addressed during paving. Within two months of paving, work involving pavement markings, rumble strips, shoulders, additional signing, brush removal, fixed objects, guardrail, and delineation would be completed..

One portion of a Transportation Research Board (TRB) state-of-the-art report dealt with the effect of resurfacing on highway safety (7). For rural resurfacing projects selected because of structural quality or poor riding condition, there was a small, immediate increase in overall crash experience (averaging about 2 percent). This increase resulted from a 10 percent increase in dry pavement crashes and a similar decrease in wet pavement crashes. For rural projects resurfaced because of wet pavement crashes, there was an average reduction of about 20 percent in wet pavement crashes. The estimated change in crashes over the life of rural projects was a reduction of seven percent in wet pavement crashes with an increase of six percent in dry pavement crashes resulting in an overall increase of three percent. Following resurfacing, it was

determined that urban projects should have an average crash reduction of about 25 percent over the life of the resurfaced pavement.

One study specifically addressed the hazard associated with pavement edge dropoffs during roadway resurfacing (8). The finding was that dropoffs of four or more inches are unsafe if the roadway edge is at a 90-degree angle to the shoulder surface. Suggested solutions to shoulder dropoffs were to perform shoulder resurfacing at the same time as the roadway resurfacing, require the contractor to provide a 45 degree fillet along the edge of the roadway, and install low shoulder warning signs as a short-term solution.

3.2 Case Study Site Selection

Lists were obtained from the Kentucky Transportation Cabinet listing the roads which were part of the resurfacing program from 1998 through 2003. Following is a summary, by highway district, of the number of miles included in the resurfacing program for these years.

	Miles in Resurfacing Program						
District No.	1998	1999	2000	2001	2002	2003	Total
1	91.5	61.2	71.8	130.9	108.5	111.9	575.8
2	82.9	98.3	101.8	127.6	97.6	112.6	620.8
3	58.6	48.3	68.1	74.4	72.5	51.4	373.3
4	90.7	95.7	69.2	87.9	95.3	115.0	553.8
5	95.2	55.2	101.1	33.3	57.8	49.3	391.9
6	83.5	78.9	121.5	96.6	59.8	83.7	524.0
7	77.9	72.7	76.5	77.7	23.9	66.5	395.2
8	56.1	62.7	85.1	85.6	64.8	48.0	402.3
9	58.3	64.2	64.6	72.6	71.9	60.5	392.1
10	91.8	77.9	95.7	77.3	58.3	74.0	475.0
11	65.5	74.2	67.3	71.8	73.3	75.7	427.8
12	60.4	53.4	77.0	65.9	69.1	45.1	370.9
Total	912.4	842.7	999.7	1,001.6	852.8	893.7	5,502.9

There was an average of about 917 miles per year resurfaced for the six-year period of 1998 through 2003. The total miles resurfaced over these six years varied from about 371 miles in District 12 to about 621 miles in District 2.

The resurfacing projects completed in 1998 and 1999 were used for the before and after crash analysis. Crash data were available for three years of both before and after data, excluding the year of resurfacing, for these projects. All resurfacing projects completed in 1998 and 1999 with a length of 5 miles or more were included in this analysis. The lists of resurfacing projects in other years were used for identifying control sections.

The list of resurfacing projects for 2003 was used to locate roads for speed data collection and for inspections of the resurfacing process. Contacts were made with the highway

district offices to determine when the resurfacing was being performed.

3.3 Before and After Crash Analysis

Before and after crash data were summarized for all roads, with a minimum length of five miles, resurfaced in 1998 and 1999. There were 120 locations which met the minimum length criteria with a total length for all locations of about 838 miles. Three years of data both before and after the year of resurfacing were summarized. In addition to total crashes, the number of crashes on a wet pavement, injury or fatal crashes, crashes during darkness, single vehicle crashes, and crashes at intersections were summarized.

Control sections were identified for each of the 120 locations with the same data summarized at these locations. In some instances, a section adjacent to the resurfaced location was used. However, the control section had to have similar characteristics with the resurfacing location. Also, the resurfacing contracts were reviewed to ensure that there was no subsequent resurfacing on the control section. There were 666 miles identified for the control sections. Following is a summary of the results of the analysis. Data for the individual locations are given in Appendix A.

	Resurfaced Locations			Control Sections		
	Number Crashes		Percent	Number Crashes		Percent
	Before	After	Change	Before	After	Change
Total Crashes	6,688	6,865	+2.6	5,236	5,260	+0.5
Wet Pavement	1,644	1,348	-18.0	1,265	1,133	-10.4
Injury/Fatal Crash	2,359	2,322	-1.6	1,698	1,655	-2.8
Darkness	1,765	1,821	+3.2	1,235	1,228	-0.9
Single Vehicle	2,473	2,669	+7.9	1,817	1,890	+3.6
Intersection	2,298	1,871	-18.7	1,693	1,492	-11.8

The before and after analysis does not show a reduction in total crashes as a result of the resurfacing projects. The crash rates changed from 188 C/100MVM (crashes per 100 million vehicle miles) before to 193 C/100MVM after for the resurfaced locations. This compares to a change from 202 C/100MVM before to 204 C/100MVM after for the control sections. These rates show the control sections were similar to the resurfaced locations. Also, the rates show that these locations did not have high rates compared to statewide averages. The most recent data show the average statewide rate for rural, two lane roads is 250 C/100MVM (9).

The largest reductions in crashes were for crashes on a wet pavement or at an intersection. When compared to the control sections, the largest reduction at the resurfaced locations was for crashes on a wet pavement.

Of the 120 resurfaced sections, the total number of crashes in the after period decreased in 57 instances, increased in 56, and remained the same at 7 locations. This compares to the control sections where the total number of crashes in the after period decreased at 52 locations,

increased at 61, and remained the same at 7 locations. At the resurfaced locations, the number of wet pavement crashes decreased at 74 locations, increased at 38, and remained the same at 8 locations. This compares to the control sections were the number of wet pavement crashes decreased at 62 locations, increased at 46 locations, and remained the same at 12 locations.

There were 77 fatal crashes identified at the resurfaced locations in the three years after the roads were resurfaced. A copy of these reports were obtained and reviewed to determine if the pavement may have been a factor. The only pattern noted which could be related to the paving operation involved the shoulder. There were 10 crashes in which a driver allowed the vehicle to drop off the road and then overcorrected with most resulting in a head on collision. While it cannot be assumed that a shoulder dropoff contributed to the driver's overcorrection, this is the type of crash typically associated with a shoulder dropoff.

3.4 Crashes with Shoulder Contributing Factor on Crash Report

All crashes statewide which had a code indicating the investigating police officer felt that the condition of the shoulder was a contributing factor in the crash were identified. For the three years of 2000 through 2002, there were 1,111 crashes in which this code was listed with 16 of these crashes involving a fatality. Of the 16 fatal crashes, 10 occurred on a state-maintained road. Following is a list, by county and route, of the routes which had the highest number of crashes with this code listed.

County	Route	Number
Pike	KY 194	17
Boone	KY 338	7
Bourbon	US 460	6
Jessamine	US 68	6
Scott	KY 32	6
Daviess	US 60	5
Hart	KY 1357	5
Kenton	I 75	5
McCracken	KY 1286	5
Pike	KY 632	5

The crash data show that a very small percentage of all crashes list a shoulder-related contributing factor. For 2002 crash data, the percentage is 0.26 for all crashes and 0.62 for fatal crashes.

3.5 Speed Analysis

Data were collected at 24 locations before and after the road was resurfaced in 2003. Data were collected at each site using a radar device with the objective of collecting data for 100

vehicles (unless the road had a very low volume). The volume was sufficient to obtain a sample of 100 vehicles except for a few roads where a minimum of about 50 vehicles was observed. Data were obtained on a section of the road were roadway geometrics (curvature and grade) did not reduce travel speeds to below what was considered to be a typical level on the road. The roads were in rural areas with a speed limit 55 mph. The roads had various pavement and shoulder widths with varying typical operating speeds. Following is a summary of the speed data before and after resurfacing.

		50TH PERCENTILE (MPH)			85TH PERCENTILE (MPH)		
COUNTY	ROUTE	BEFORE	AFTER	CHANGE	BEFORE	AFTER	CHANGE
Barren	KY 90	58.3	56.7	-1.6	62.3	61.3	-1.0
Estill	KY 1571	47.3	50.4	+3.1	52.5	56.3	+3.9
Fayette	KY 418	43.5	45.0	+1.5	49.5	50.6	+1.1
Fayette	KY 859	54.5	54.6	+0.1	60.4	59.5	-0.9
Hardin	KY 313	55.2	55.0	-0.2	59.4	59.2	-0.2
Hardin	KY 1646	51.6	51.4	- 0.2	56.6	55.6	-1.0
Hopkins	US 62	56.7	56.1	-0.6	61.2	60.8	-0.4
Hopkins	KY 138	50.5	51.5	+1.0	58.0	59.2	+1.2
Laurel	KY 490	45.8	47.9	+2.1	50.9	51.7	+0.8
Lee	KY 52	39.7	40.7	+1.0	43.6	45.5	+1.9
Leslie	KY 699	43.3	44.7	+1.4	50.3	51.5	+1.2
Lincoln	US 127	59.1	59.2	+0.1	63.1	63.3	+0.2
Livingston	KY 453	54.2	57.5	+3.3	60.3	60.9	+0.6
McCracken	KY 305	47.3	49.0	+1.7	52.2	54.2	+2.0
McCracken	KY 358	47.6	49.8	+2.2	52.5	54.2	+1.7
Mercer	US 68	53.7	52.5	-1.2	60.4	58.5	-1.9
Mercer	US 127	59.4	57.8	-1.6	63.9	64.5	+0.6
Nelson	KY 48	50.8	51.9	+1.1	58.0	58.1	+0.1
Nelson	KY 52	56.0	57.2	+1.2	64.0	61.8	-2.2
Nelson	KY 55	49.5	53.0	+3.5	57.0	58.7	+1.7
Nelson	KY 245	57.4	57.5	+0.1	62.1	62.2	+0.1
Perry	KY 80	43.3	43.7	+0.4	47.2	50.0	+2.8
Powell	KY 213	34.3	37.4	+3.1	38.2	41.7	+3.5
Wolfe	Mt. Pkwy.	60.2	60.1	-0.1	64.5	64.0	-0.5

When considering all the data, the 85th percentile speed increased in 16 cases and decreased in 8 cases with an average change of +0.6 mph. The 50th percentile speed increased in 17 cases and decreased in 7 cases with an average change of +0.9 mph. While there was an overall small increase in speed, the data do not support an opinion that resurfacing roads results in a substantial increase in travel speeds. Some of the largest increases were on roads with the lowest speeds prior to resurfacing.

3.6 Inspection of Resurfacing Projects

Considering projects inspected during the resurfacing process, locations where speed data were collected, and locations inspected after the resurfacing was completed, a total of 70 resurfacing projects were inspected. Projects were inspected in all 12 highway districts. Following is a list of the 20 locations where there an inspection was made during a portion of the resurfacing project. The list includes the county and route where the resurfacing was being conducted as well as the contractor.

COUNTY	ROUTE	CONTRACTOR
Estill	KY 1571	Hinkle Construction
Fayette	US 60	Central Kentucky Asphalt
Franklin	Interstate 64	Mayes Construction
Garrard	KY 152	Allen Company
Harrison	KY 32	Hinkle Construction
Henderson	US 60	Rogers Group
Hopkins	US 62	Roadbuilders
Hopkins	KY 70	Roadbuilders
Letcher	US 119	Mountain Enterprises
Lincoln	US 27	Allen Company
Livingston	KY 70	Jim Smith Pavers
Madison	KY 52	Allen Company
Nelson	KY 52	Mago Construction
Nelson	KY 55	Mago Construction
Ohio	KY 136	Scotty's Contracting
Ohio	WK Parkway	Scotty's Contracting
Pike	US 23	Mountain Enterprises
Powell	KY 213	Hinkle Construction
Pulaski	KY 80	Hinkle Construction
Wolfe	Mt. Parkway	Hinkle Construction

During the inspection, an attempt was made to discuss the project with the inspector for the Transportation Cabinet and/or the contractor. Ten different contractors were included in these inspections. Inspections were made during various phases of the resurfacing process. Many were made during the paving operation with some made during the leveling or shoulder preparation phase.

The comments obtained from the inspectors and contractors were summarized and considered when the recommendations were developed. The comments could be placed in several general categories. The most common observations dealt with preparation of the road, placement of the shoulder wedge, and the paving operation. Following is a summary of the most frequent comments.

- The amount of material set up for leveling is not adequate.
- It is very difficult to obtain a change order to increase the amount of material when the amount of material set up in the contract is inadequate.

- The amount of leveling material does not allow corrections to be made for pavement failures.
- There should be additional preparation of the shoulder prior to placement of the shoulder wedge.
- There should be more coordination with maintenance related to preparation of the road prior to resurfacing and needed corrections after resurfacing.
- Leveling may be improved using a grader, rather than the paver, if there is an experienced grader operator available since the paver just follows the existing pavement profile.
- For the large majority of roads, it is not feasible to use the electronics on the paver to set the pavement cross slope due the amount of material which would be required. However, a "smartlevel" could be used to check the template at locations where a correction appears to be warranted.
- Adding the shoulder wedge in some instances extends the pavement to the start of the downslope to the ditch line. Ditching and shouldering adjustments are needed in these instances.
- Contractors typically preferred to place the shoulder wedge at the same time as the adjacent lane (monolithically).
- The reasons given for placing the shoulder wedge separately in some instances relate to being able to slope the shoulder wedge down to within one inch of the adjacent turf and using a different material for the shoulder which gives a visual distinction for the driver.
- Milling and recycling could be used in more instances with the milled material used to correct shoulder problems.
- The optimum method to use to place the shoulder is to trench prior to placement to establish a proper base and then pave the shoulder along with the adjacent lane.
- An amount of DGA could be included in the contract to use to correct shoulder problems.

3.7 Board of Claims Cases

Summaries have been prepared for cases filed through the Board of Claims alleging a roadway related problem contributed to a traffic crash (1). These summaries have included a listing by the reason for the claim. The reasons which could relate to the roadway surface condition are: improper drainage, crash due to pavement, shoulder dropoff, and shoulder related defect. Claims related to drainage and the shoulder were some of the largest claim amounts.

When considering claims of $50,000 or more, the reason for the largest number of claims dealt with improper drainage. These claims dealt with either water not draining properly off the road or the adjacent drainage facility allowing water to accumulate on the pavement. The reasons given for these claims which would relate to the pavement were rutting which allowed water to accumulate in the wheel paths or the pavement cross slope not draining the water properly from the pavement.

There were a large number of claims with high dollar amounts which dealt with the condition of the shoulder. The reasons for the claim that related to resurfacing dealt with leaving

a dropoff at the edge of the pavement or having a large difference in elevation between the edge of the travel lane and adjacent shoulder.

Another reason for some claims which dealt with resurfacing concerned the pavement cross slope. A typical claim in this category noted the lack of proper crown or superelevation.

4.0 CONCLUSIONS

Following is a list of major conclusions from the analysis.

1. An analysis of the before and after crash data did not find a reduction in total crashes after resurfacing. There was a reduction in crashes which occurred on a wet pavement.

2. A comparison of speeds before and after resurfacing did not find a major change in travel speeds. Considering all locations, there was an average increase in speeds after resurfacing of less than one mph.

3. Discussion with state inspectors and contractors found agreement of areas which could be changed to improve the resurfacing process. Most of the comments dealt with the general areas of preparation of the road prior to paving, methods to place the shoulder wedge, and methods to improve the paving operation.

5.0 RECOMMENDATIONS

The following recommendations should be considered when resurfacing roads. They were grouped into a few general categories.

Preparation for Resurfacing

- Consider adding ditching and shouldering as part of preparation for resurfacing especially when the new pavement extends to the ditch fore slope (either by the contractor or the Kentucky Transportation Cabinet (KYTC))
- Repair pavement and edge failures prior to resurfacing (either by the contractor or by KYTC maintenance)

- Consider additional use of milling in rural areas to correct shoulder or pavement cross slope problems (ensure that an adequate depth of surface material is available before milling) and then use the milled material as a DGA-type material along areas of the shoulder where large differences in elevation could not be eliminated
- As an alternative to using a paver, consider an experienced grader operator for leveling and patching (a grader provides the potential for better leveling than a paver which follows the existing pavement contour)
- As part of the pre-resurfacing preparation by the maintenance engineer, emphasize

inspection of the road to locate pavement and shoulder failures to repair prior to resurfacing and ditching

Shoulder-Related Issues

- When the pavement width allows an edgeline, provide a rumble strip on the shoulder or shoulder wedge; when the pavement width does not allow an edgeline, the shoulder wedge could use either a rumble strip or a different material to distinguish the shoulder from the adjacent travel lane
- Add specified amount of DGA in the contract for use at shoulder problem locations
- Place a note on the typical section that the shoulder wedge should be sloped down to the adjacent turf at no more than a 45 degree angle (devices have been developed to achieve this wedge angle)
- When the pavement is of sufficient width to have an edgeline, pave the shoulder wedge as the adjacent lane is paved (devices have been developed to achieve this wedge angle)
- Consider placing the shoulder wedge separately with a different mix to distinguish it from the travel lane when the road width does not allow placement of an edgeline
- Trenching should be considered prior to adding a paved shoulder wedge in order to provide a proper base (use base material in trenching operation and then surface material so use two lifts for the shoulder)
- If a DGA material is used for the shoulder, the project should include a binder to stabilize this material
- As part of preparation for the shoulder wedge, remove the grass down to the dirt (if not placing over pavement)
- Inspect grooving of shoulder to ensure that a proper depth is obtained (grooves should be milled when feasible)
- Ensure that the shoulder wedge height is not excessive at driveways and pulloffs
- Place low shoulder signs during resurfacing and leave these signs after completion of the resurfacing if any shoulder problem is noted

Paving Operation

- Allow for change orders to increase material to ensure adequate resurfacing material
- Where practical (especially on roads which were originally constructed with crown and superelevation guidelines), encourage use of the paver electronics to maintain proper crown and superelevation or, as a minimum, use a “smartlevel” to check the pavement cross slope (an option is to use the electronics during the leveling operation)
- Use a material transfer vehicle when conditions permit on high volume, high speed roadways

General Issues

- Place a note on the typical section in the resurfacing contract that leveling is used to improve the pavement cross slope but new construction guidelines do not apply to resurfacing projects
- Ensure that an adequate amount of leveling material is included in the contract (use of an automated road surface analyzer device may be considered as a method to determine the

proper amount of leveling material)

- Encourage use of the placement of appropriate signs and markings after resurfacing as an addition to the contract to minimize any potential problems after resurfacing (for example, place object markers when there is a potential hazard such as a culvert headwall adjacent to the pavement)
- Allow the resident engineer and inspector to respond to unanticipated changes to ensure the optimum possible pavement cross section and adjacent shoulder area are provided by the resurfacing project
- Work with maintenance after the surfacing is complete to correct any problems noted which could not be addressed as part of the resurfacing contract
- Place edgelines after resurfacing if the completed road has a width of 20 feet or more (not including the shoulder wedge)
- Consider the addition of milled centerline rumble strips on two lane roads where there are 12-foot lanes
- Allow a sufficient time when drains are placed under the road prior to resurfacing to allow for settlement prior to paving
- Consider development of a more comprehensive policy for resurfacing that focuses both on the paved travel lanes and the adjacent roadside (shoulder, ditch, clear zone)

6.0 REFERENCES

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Appendix A. Before and After Crash Data

TABLE A-1. RESURFACING BEFORE AND AFTER CRASH DATA

						Crashes		Wet Crashes		Fatal Crash		Injury Crash		Dark Crash		Single Unit Crash		Intersection Crash	
County	Route	Location	Year	BMP	EMP	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Anderson	US 62	Nelson Co Line/KY 53 S	1998	0.000	10.281	39	33	7	10	2	0	13	14	10	10	25	23	5	2
Ballard	US 60	Big Cane Creek/Wayside Inn	1998	2.422	9.550	91	68	25	7	1	0	31	19	22	23	41	29	14	18
Ballard	KY 286	KY 121/McCracken Co. line	1999	0.000	14.415	95	78	13	6	1	0	29	28	30	19	66	52	12	13
Bell	US 25E	KY 188/KY 190	1998	6.402	11.746	60	52	11	11	1	1	28	19	19	13	26	20	11	3
Bourbon	US 68	US 68X/Hinkston Cr. Br.	1999	2.360	9.405	124	113	30	21	1	0	30	40	29	23	44	37	54	43
Bourbon	US 460	Scott Co. Line/US 27-US 68 @ Paris	1999	0.000	7.696	85	82	16	11	5	1	22	25	22	26	48	51	25	16
Boyd	US 23	KY 752/I-64	1998	3.024	10.678	97	101	24	12	0	0	34	41	31	33	43	38	37	37
Boyd	US 60	KY 180/KY 1134	1999	4.023	9.638	306	313	47	55	0	1	91	88	57	70	49	48	169	107
Boyle	KY 34	KY 300/US 127 Bypass	1999	6.298	12.262	73	38	24	6	0	1	24	14	20	5	29	21	18	8
Breathitt	KY 476	Perry Co. Line/KY 15	1999	0.000	11.446	33	29	10	8	1	1	18	13	11	11	18	14	3	0
Breckinridge	KY 144	KY259/KY 376	1998	14.377	19.450	9	9	2	2	1	1	2	6	2	3	7	5	1	1
Breckinridge	KY 401	KY 259 @ Madrid/KY 86 @ Dyer	1999	0.000	10.240	13	12	4	2	0	0	9	0	3	2	6	4	1	0
Bullitt	KY 61	I-65/KY 251	1998	2.020	7.468	60	51	11	6	0	0	23	18	10	20	17	19	17	14
Bullitt	KY 480	KY 1604/Nelson Co. Line	1999	5.468	11.645	27	24	3	3	0	0	7	9	7	12	16	18	5	5
Butler	KY 79	KY 340 West/Grayson Co. Line	1998	19.149	24.955	16	12	1	0	1	0	6	7	2	2	7	4	0	4
Butler	KY 70	South Hill Muddy Cr Rd/US 231	1999	6.383	14.419	55	78	19	17	0	0	23	21	16	16	17	23	22	36
Calloway	KY 94	KY 893/KY 822	1999	2.756	9.249	77	92	21	22	0	0	23	22	16	20	22	30	51	44
Calloway	KY 121	KY 783 South/Graves Co. Line	1999	17.855	24.156	55	80	19	11	0	1	17	24	9	27	17	44	27	15
Campbell	US 27	Pendleton Co. Line/Beg New Construction	1999	0.000	8.340	310	326	68	80	1	3	79	89	96	81	91	77	130	92
Carlisle	US 62	US 51/Bridge over Mayfield Creek	1998	0.000	12.978	18	30	4	5	1	1	5	12	2	10	7	14	5	11
Carroll	KY 227	Owen Co. Line/KY 36	1998	0.000	6.816	181	192	52	33	0	0	43	52	53	54	54	48	43	52
Casey	KY 80	Russell Co. Line/Pulaski Co. Line	1999	0.000	5.144	14	18	3	4	0	0	2	7	5	6	7	9	0	1
Casey	KY 206	Adair/Casey Co. Line/KY 70	1999	0.000	5.276	5	6	2	0	0	0	2	3	1	1	2	5	3	1
Christian	KY 91	US 68/KY 624	1999	0.000	11.078	66	49	10	9	1	0	21	16	19	12	34	29	16	9
Christian	KY 107	KY 117/KY3493	1999	8.246	15.681	57	36	10	6	0	0	17	11	11	9	13	11	33	14
Christian	KY 107	KY 507/KY 189 N	1999	19.844	30.351	108	100	27	18	0	0	35	33	24	33	26	42	45	30
Clinton	KY 90	US 127/Wayne Co. Line	1999	5.257	12.816	13	25	5	3	1	0	4	11	6	5	3	8	12	14
Cumberland	KY 90	KY 61 S/Bear Cr. Br.	1998	14.113	20.250	25	14	7	2	1	1	4	3	6	5	13	6	5	2
Estill	KY 82	KY 89/Powell Co. Line	1999	0.000	5.029	39	21	15	4	0	0	13	9	13	10	28	13	6	2
Fayette	US 25	I-75/KY 418	1999	0.000	8.244	119	177	27	35	1	3	43	60	33	60	39	59	59	62
Fleming	KY 57	Sleepy Run/Lewis Co. Line	1998	12.023	18.704	27	18	11	6	0	0	8	5	9	6	16	12	1	2
Fleming	KY 11	KY 1336/KY 32	1999	5.435	10.630	33	20	8	3	0	2	15	7	6	2	15	5	10	7
Fleming	KY 1013	KY 158/KY 32	1999	0.000	6.256	10	4	3	0	0	0	4	1	8	2	10	2	2	0
Floyd	KY 7	KY 550/Magoffin Co. Line	1999	5.377	12.787	45	58	13	11	0	1	21	35	12	12	20	18	11	11
Fulton	KY 166	KY 239/US 45 South	1998	5.106	13.279	32	21	7	1	0	0	13	8	8	13	16	16	10	1
Green	KY 61	KY 566/ Larue Co. Line	1999	18.637	24.344	31	21	1	5	0	0	11	12	14	6	19	20	1	2
Greenup	US 23	Siloam Lane/Grant Bridge	1999	23.002	28.760	66	62	12	12	1	0	26	19	21	16	21	15	24	28
Hardin	KY 84	KY 920/Old Meeting Creek Rd	1998	4.185	9.423	10	8	3	0	0	1	3	1	6	3	8	6	0	1
Hardin	KY 86	Breckinridge Co. Line/KY 920	1998	0.000	5.287	17	30	3	4	1	1	6	10	3	10	7	17	3	3
Hardin	KY 86	KY 920/US 62	1999	5.287	16.145	70	74	12	7	1	2	22	19	16	18	33	32	17	10
Hardin	KY 1600	KY 220/Meade Co. Line	1999	6.121	11.471	50	46	11	1	0	1	16	15	14	13	23	17	17	13
Harlan	US 119	Clem Rd/Totz Connect	1999	20.200	26.000	27	32	4	6	1	0	3	5	11	8	20	17	1	2
Harrison	US 27	Carr Rd/Pendleton Co. Line	1998	14.400	19.472	14	20	2	4	0	0	6	4	4	10	10	18	0	1
Hart	KY 88	US 31W/US 31E	1998	17.817	23.908	33	20	5	4	0	1	11	7	7	7	12	10	4	2
Hart	KY 88	US 31E/Green CO. Line	1999	23.908	30.482	11	18	1	5	0	1	5	4	2	7	6	10	3	4
Hart	US 31W	Barren Co. Line/Green River Bridge	1999	0.000	10.045	61	99	19	23	0	1	28	36	16	21	11	15	31	22
Henry	KY 22	KY 1360/Owen Co. Line	1998	16.584	22.528	14	18	3	4	1	0	4	6	7	7	9	12	3	1
Henry	KY 1606	KY 146/RR Crossing	1998	0.000	5.739	5	5	3	2	0	0	2	1	2	4	4	5	1	0

TABLE A-1. RESURFACING BEFORE AND AFTER CRASH DATA (CONTINUED)

						Crashes		Wet Crashes		Fatal Crash		Injury Crash		Dark Crash		Single Unit Crash		Intersection Crash	
County	Route	Location	Year	BMP	EMP	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Henry	KY 22	US 421/KY 1360	1999	9.712	16.584	26	17	5	4	1	1	8	5	7	7	14	9	6	0
Hickman	KY 58	US 51/Barkley Rd.	1999	10.146	15.429	9	16	1	1	0	0	3	3	1	6	4	11	4	2
Hopkins	KY 70	KY 109/KY 1337	1999	7.096	12.331	46	46	8	7	0	0	12	13	8	23	23	39	8	4
Jackson	KY 89	Rockcastle Co. Line/KY 2002	1999	0.000	5.681	3	3	1	0	0	0	0	0	1	1	2	1	0	0
Jackson	KY 89	Carlton Rd/Estill Co. Line	1999	21.735	31.750	10	11	5	2	0	0	4	7	1	4	6	7	0	3
Johnson	US 460	Magoffin Co. Line/KY 40	1999	0.000	7.809	51	37	7	9	1	0	16	22	14	9	20	14	26	9
Kenton	KY 16	KY 17 S/ KY 2047 W	1998	3.646	9.323	131	141	37	25	0	0	55	44	31	44	50	62	45	42
Kenton	KY 177	Vises Trail/Decoursey Cr. Br.	1998	8.336	15.225	84	80	20	10	0	0	36	23	25	17	47	48	17	12
Knott	KY 7	Dry Creek Rd/ Floyd Co. Line	1998	9.778	16.039	33	26	12	9	0	2	15	12	5	7	16	14	2	3
Knott	KY 550	Montgomery Cr. Br/ KY 2759	1998	4.121	9.550	20	22	7	8	0	1	7	6	4	5	8	13	9	3
Knox	US 25E	KY 229/KY 233	1998	14.473	21.715	76	86	17	8	4	1	30	27	21	32	37	37	13	25
Knox	KY 11	US 25E/KY 1304	1999	10.118	16.293	109	116	54	39	0	2	51	47	14	13	24	36	32	16
Larue	KY 84	Barren Run Bridge/US 31E	1998	3.475	9.033	24	24	10	6	0	1	6	7	8	3	13	14	9	1
Laurel	KY 192	KY 552/I-75 Overpass	1999	12.590	18.243	94	125	27	21	1	1	31	29	17	23	21	24	56	57
Lee	KY 52	KY 2016 St. Helens	1999	17.057	22.730	15	10	5	3	2	1	2	3	4	4	11	6	1	1
Leslie	KY 699	Maggards Branch Bridge/Old Big Rock Rd.	1998	8.137	13.559	14	13	0	1	0	0	8	10	5	3	9	10	0	0
Letcher	KY 7	County Rd/Caudill Creek Rd.	1998	0.307	8.044	43	31	8	5	1	0	21	15	6	6	15	14	5	1
Letcher	KY 160	KY 463/ KY 931	1998	1.854	9.477	16	17	5	4	0	0	7	9	2	3	7	8	0	3
Letcher	KY 931	KY 15X/KY 7	1999	10.239	18.388	38	42	10	6	0	0	17	18	7	7	19	20	0	7
Lewis	KY 8	KY 8 Conn/Greenup Co. Line	1998	28.575	36.910	49	87	9	14	0	3	25	29	20	27	40	56	1	5
Lincoln	KY 78	New US 127/KY 300	1998	2.188	11.479	36	51	9	13	0	1	19	25	11	13	22	32	10	12
Logan	US 431	Red Oak Ch. Rd/ US 79	1998	7.337	13.896	121	78	25	13	1	1	43	26	20	22	29	25	48	29
Madison	KY 627	US 25/Clark Co Line	1998	0.000	6.074	103	90	28	19	1	1	32	29	31	19	29	25	42	40
Magoffin	KY 2019	US 460/KY 1081	1998	0.000	5.574	20	20	7	3	0	0	8	12	5	8	10	12	2	4
Marion	US 68	New Pavement/KY 426	1998	2.479	8.629	28	40	1	7	1	1	9	10	16	19	13	23	6	11
Marshall	US 62	McCracken Co. Line/KY 95	1998	0.000	7.200	93	60	23	11	2	0	25	24	19	13	22	18	39	24
Mason	KY 324	US 68/KY 11	1998	4.903	10.766	13	11	2	1	0	0	3	4	4	4	5	7	2	3
McCracken	US 45	Graves Co. Line/KY 1241	1999	0.000	5.792	88	97	23	17	2	1	31	22	25	27	20	24	57	65
McCreary	KY 92	KY 1044/Whitley Co. Line	1998	18.722	25.737	19	16	7	2	1	1	11	6	6	2	11	7	2	4
McLean	KY 85	KY 81/Fox Hollow Rd.	1998	2.632	9.295	21	18	4	2	0	0	5	8	5	10	11	13	5	3
McLean	KY 81	Revelett-Stroud Rd/Walnut St.	1999	5.398	11.395	38	24	23	4	0	1	10	9	10	9	15	17	12	4
Menifee	KY 77	Correctional Facility RD/US 460	1999	2.990	9.998	9	10	2	1	0	1	3	3	3	3	5	9	2	0
Monroe	KY 63	Barren Rvr East Fork Bridge/Barren Co. Line	1998	14.313	21.214	1	3	0	0	0	0	1	1	0	1	0	1	1	0
Montgomery	KY 11	Powell CO. Line/KY 646 S	1998	0.000	7.067	68	107	16	34	3	0	18	37	29	30	35	56	6	15
Montgomery	KY 686	US 460W/US 60 East	1999	0.000	6.241	258	297	96	65	3	3	77	81	44	45	9	15	219	152
Morgan	KY 519	Pleasant Run Crk. Br./Rowan Co. Line	1998	3.940	10.544	34	27	9	4	2	0	11	4	14	11	25	19	0	1
Muhlenberg	US 62	US 431/W. End Rockport Rd	1999	17.930	25.807	41	51	13	10	2	0	9	20	14	9	28	25	8	10
Nelson	KY 49	Marion Co. Line/Beech Fork Branch	1998	0.000	6.000	46	35	8	4	0	1	19	11	17	15	25	28	3	1
Nelson	US 31E	KY 245/KY509	1998	15.478	20.536	84	122	16	24	1	1	25	34	22	30	25	31	25	40
Nelson	US 150	KY 49/Washington Co. Line	1999	0.510	7.682	89	164	13	43	1	3	30	47	35	33	26	37	30	80
Nicholas	KY 36	KY 32/Bath Co. Line	1999	3.283	12.807	81	56	25	15	0	2	23	22	17	23	24	37	25	2
Ohio	KY 69	KY 54 West/Hancock Co. Line	1998	31.623	37.339	13	12	1	2	2	0	7	5	4	7	4	9	0	0
Owen	KY 355	KY 1982/KY227	1998	12.487	18.970	23	30	3	4	1	0	9	11	8	11	13	19	2	3
Owen	KY 22	KY River Bridge./US 127	1999	0.000	9.351	44	55	13	12	1	1	13	14	11	12	26	27	8	13
Pendleton	US 27	New Pavement/Campbell Co. Line	1998	13.223	19.422	72	61	15	9	1	1	27	14	30	26	42	29	13	13
Pendleton	KY 1053	KY 3180/US 27	1999	3.359	9.586	2	4	1	1	0	0	1	2	1	2	2	4	0	0
Perry	KY 463	Letcher Co. Line/KY 699	1998	0.000	6.521	8	13	1	5	1	0	4	6	1	5	4	9	1	2
Perry	KY 476	KY 1087/KY 267	1998	12.444	18.407	17	7	4	1	0	0	5	6	3	4	8	6	0	0

TABLE A-1. RESURFACING BEFORE AND AFTER CRASH DATA (CONTINUED)

						Crashes		Wet Crashes		Fatal Crash		Injury Crash		Dark Crash		Single Unit Crash		Intersection Crash	
County	**Route**	**Location**	**Year**	**BMP**	**EMP**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Perry	KY 2022	KY 484/KY 28 @ Buckhorn	1998	0.000	8.177	8	10	2	3	0	0	2	4	1	1	3	1	0	0
Perry	KY 15	Bridge over KY 7/KY 15X	1999	5.961	11.119	128	126	33	27	0	0	61	59	30	24	32	30	74	35
Pike	KY 195	KY 611/US 460 & KY 80	1999	5.340	11.560	97	70	26	31	0	0	54	43	38	23	52	41	10	2
Pulaski	KY 80	Casey Co. Line/Hatfield Rd	1998	0.000	6.665	111	96	31	17	1	1	22	23	14	17	20	23	58	42
Russell	KY 80	US 127/Casey Co. Line	1999	3.958	10.564	46	54	6	13	1	0	17	21	14	14	15	21	20	18
Scott	US 460	I-75/Bourbon Co. Line	1998	8.889	15.421	153	98	49	16	1	1	44	37	18	21	42	41	61	18
Shelby	KY 12	KY 43/KY1005	1998	0.000	5.828	25	16	6	4	0	1	12	3	9	8	12	10	2	0
Shelby	KY 43	KY 55/Washburn Rd.	1999	0.000	8.015	31	61	10	23	1	1	10	12	17	22	20	42	5	11
Simpson	KY 100	I-65 Underpass/Allen Co. Line	1998	12.775	19.048	46	63	10	12	2	1	21	15	19	15	15	24	9	9
Todd	KY 181	Herman Rd/KY 171	1998	7.805	15.175	59	53	20	10	0	0	20	11	14	9	26	16	17	13
Todd	KY 181	US 79 @ Tiny Town/Hermon Rd.	1999	0.000	7.805	41	29	7	4	0	1	15	10	10	4	19	16	10	9
Trigg	KY 139	TN State Line/KY 164	1998	0.000	6.257	21	10	3	1	0	0	9	3	7	5	9	7	7	2
Trimble	US 421	Henry Co. Line/US 42S	1998	0.000	6.704	42	57	10	19	0	1	17	19	13	15	31	40	4	5
Union	KY 56	End curb & gutter/Webster Co. Line	1998	13.532	23.184	50	65	4	5	0	1	15	20	24	26	33	44	14	14
Union	US 60	KY 270/Eagle Creek Bridge	1999	6.754	13.059	88	73	24	13	1	1	29	30	26	19	32	31	23	19
Warren	US 31W	Simpson Co. Line/Elrod Rd.	1999	0.000	8.412	126	126	37	18	1	2	37	45	31	27	33	37	65	50
Washington	KY 55	KY 438/Nelson Co. Line	1999	9.862	16.169	11	18	2	6	0	1	3	7	2	5	5	10	3	2
Wayne	KY 92	W. Jenkins St/KY 1479	1998	9.659	16.017	57	42	15	8	0	1	21	15	11	14	16	18	17	8
Wayne	KY 776	KY 92/KY 790	1999	0.000	7.451	10	16	1	1	0	1	3	2	2	4	4	6	1	4
Webster	US 41A	KY 132/Henderson Co Line	1999	10.010	19.657	42	74	13	16	0	2	19	21	14	23	17	51	18	12
Whitley	US 25W	KY 90/PCC Pavement@ I-75 Interchange	1999	22.183	29.380	100	139	19	37	1	1	44	45	22	29	23	27	35	35
Wolfe	KY 15	KY 191/Mountain PKWY	1998	9.515	15.250	31	23	7	3	0	0	13	10	10	6	10	10	12	6
Wolfe	KY 191	KY 1812/KY 203	1999	4.977	10.342	32	34	6	8	0	1	15	15	9	9	14	14	6	8
Woodford	US 60	Franklin Co. Line/RR Crossing	1998	0.000	8.296	146	170	29	38	2	0	50	44	53	38	41	54	57	58