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I-76 Truck Study

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13. ABSTRACT (Maximum 200 words)

Portions of the driving lane on I-76 located in CDOT's Region 4 are seriously distressed. To help prolong the life of the Portland Cement Concrete Pavement Region 4 has placed signs advising truckers to use the passing lane between Roggen and the Nebraska state line approximately 140 miles. According to a survey conducted by the Colorado Department of Transportation, 90% of the total truck traffic is concentrated in the driving lane. Both lanes are subjected to the same environmental stresses but the driving lane has become prematurely distressed due to the damage caused by the heavy truck loads.

A test section well within the signed test area advising the truckers to use the passing lane and a control section just prior to the signed area were established and evaluated over a four year period. Roughness data taken with an Ames Profilograph, slab faulting measured with a Georgia fault meter, and overall physical pavement distress were noted and used as a comparison between driving lane and passing lane within the two sections.

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I. INTRODUCTION

Portions of the driving lane on I-76 in Region IV are seriously distressed. To help prolong the life of the Portland Cement Concrete Pavement (PCCP), Region IV placed signs advising truckers to use the passing lane between Roggen and the Nebraska State line in early 1990. Signs were placed for a total of 140 miles on I-76 as shown in photo 1. According to a survey conducted by the Colorado Department of Transportation prior to this experiment, 90% of the total truck traffic was concentrated in the driving lane. Both lanes are subjected to the same environmental stresses but the outside driving lane has become prematurely distressed due to the damage caused by the heavy truck loads.

The evaluation looked at the effect on the pavement that placing truck traffic in the passing lane produces. On January 8, 1990, Research personnel established two 600 ft. test sections on eastbound I-76. The first section (the control section) was placed at approximately 2,000 ft. east of m.p. 35, prior to the signs asking truckers to use the left lane located at m.p. 39. The test section was placed well within the signed area at m.p. 58 eastbound. This section was reconstructed in 1991, thereby eliminating the test section and causing the study of the pavement distress to be restarted. A new test section was established in 1992 in the westbound lanes at m.p. 94. All data on this project was analyzed for the period between 1992 and 1996, giving four years of pavement data results.

Initial pavement evaluation was performed in the driving lane and passing lane on both the test section and the control section consisting of the following:

- Roughness data (taken with the Ames Profilograph)

- Slab faulting measurements (using the Georgia fault meter)

- Cracking and physical pavement distress was noted

II. PAVEMENT EVALUATIONS

Pavement evaluations were conducted on an annual basis, looking at roadway profile (using an Ames profilograph), slab faulting (using the Georgia fault meter), and a comparative evaluation of slab cracking and physical pavement distresses. Data was collected for a period of four years on the test and control locations. The data is discussed below.

A. Profilograph Testing

Profilograph testing was performed using an Ames profilograph. The multi-wheel profilograph consists of a frame twenty-five feet in length supported on wheels at either end. The profile is recorded from the vertical movement of a wheel attached to the frame at midpoint and is in reference to the mean elevation of the points of contact with the road surface established by the support wheels. For analysis a .2 inch blanking band was used on the profilogram and all readings were converted to inches per mile. Photo 2 shows the Ames profilograph that was used during this study. To help understand the profilograph results: The Colorado Department of Transportation Standard Specifications for Road and Bridge Construction specify that maximum pavement surface smoothness tolerances on new construction be equal to or less than 6 inches per mile on rural interstate highways (section 412.17). This specification is for new construction on the same type of pavement sections as the test and control section. However the test and control section are nearly 30 years old.

Table 1 shows the testing results for the test and control section over the four-year period. The control section data is shown graphically in figure 1. From this graph it can be seen that the driving lane experienced an increase in roughness of five inches per mile over the four-year period. At the same time it can be seen that the passing lane had a decrease in roughness of 2.3 inches per mile. This was the section of roadway where the truckers were not asked to drive within the passing lane (standard section of roadway). The test section shown in Figure

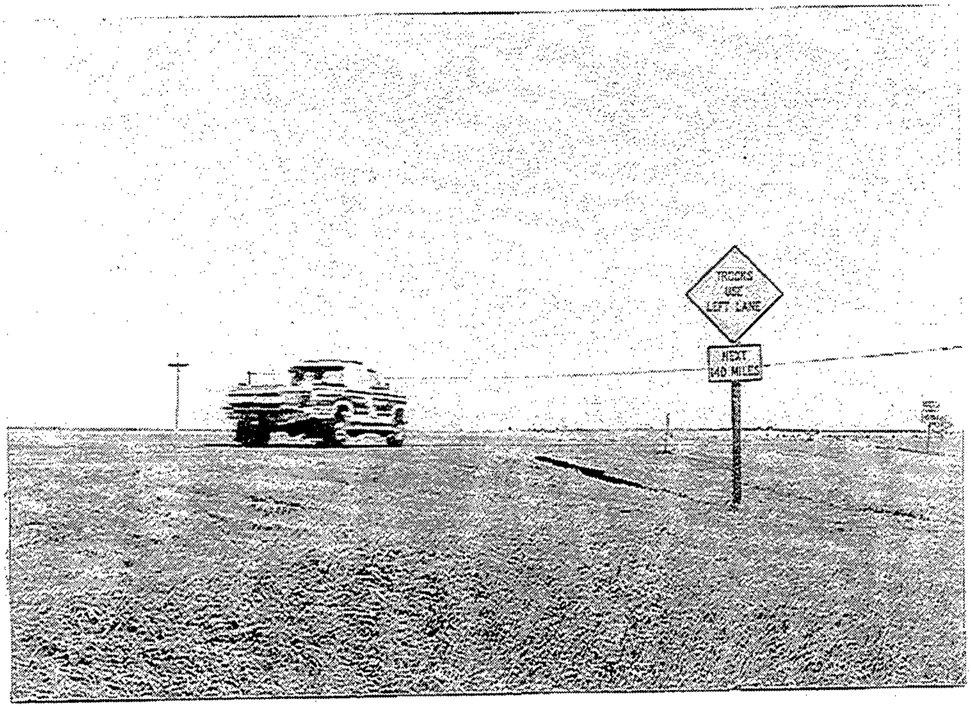


Photo 1 – Sign asking truckers to use the left lane (passing lane) next 140 miles.

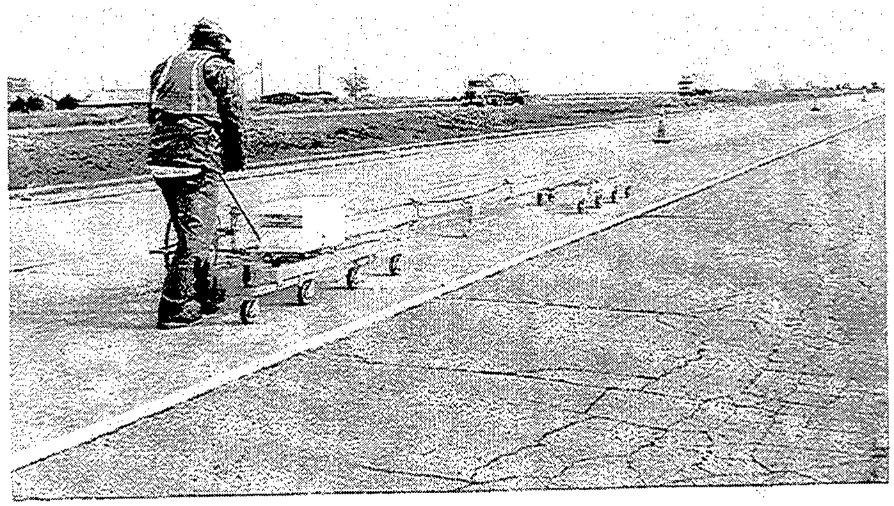


Photo 2 – Profilograph testing was performed with an Ames profilograph.

I-76 TRUCK STUDY
Profilograph Testing

CONTROL SECTION

APPROX. 2,000 FT. EAST OF M.P. 35 EASTBOUND LANES

	DRIVING LANE			PASSING LANE		
	LWP	RWP	Avg.	LWP	RWP	Avg.
2/20/92	28.1	28.2	28.15	17.4	15.3	16.35
3/23/93	32.9	36.4	34.65	20.3	18.1	19.2
12/2/94	30.6	29.7	30.15	18.1	12.7	15.4
11/6/96	34.9	31.4	33.15	15	13.2	14.1

TEST SECTION

M.P. 94 W.B.L

	DRIVING LANE			PASSING LANE		
	LWP	RWP	Avg.	LWP	RWP	Avg.
2/20/92	22.3	15.2	18.75	6.9	10.6	8.75
3/23/93	19.7	14.7	17.2	8.1	10.5	9.3
12/2/94	27.1	16.9	22	11.4	10	10.7
11/6/96	16.5	29.6	23.05	13.7	10.9	12.3

Table 1

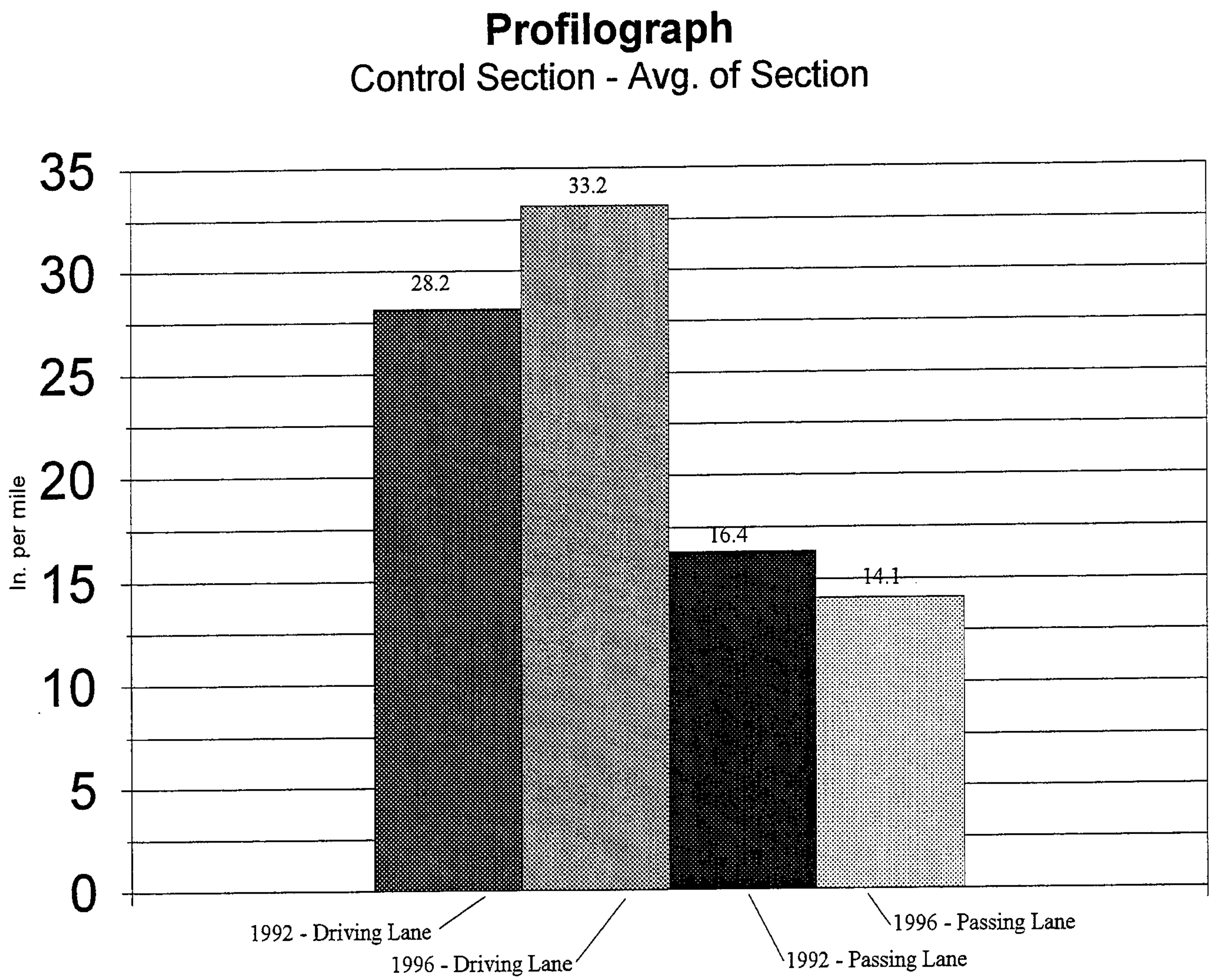

Profilograph
Control Section - Avg. of Section
35
30
25
20
15
10
5
0
In. per mile
28.2
33.2
16.4
14.1
1992 - Driving Lane
1996 - Driving Lane
1992 - Passing Lane
1996 - Passing Lane

Figure 1

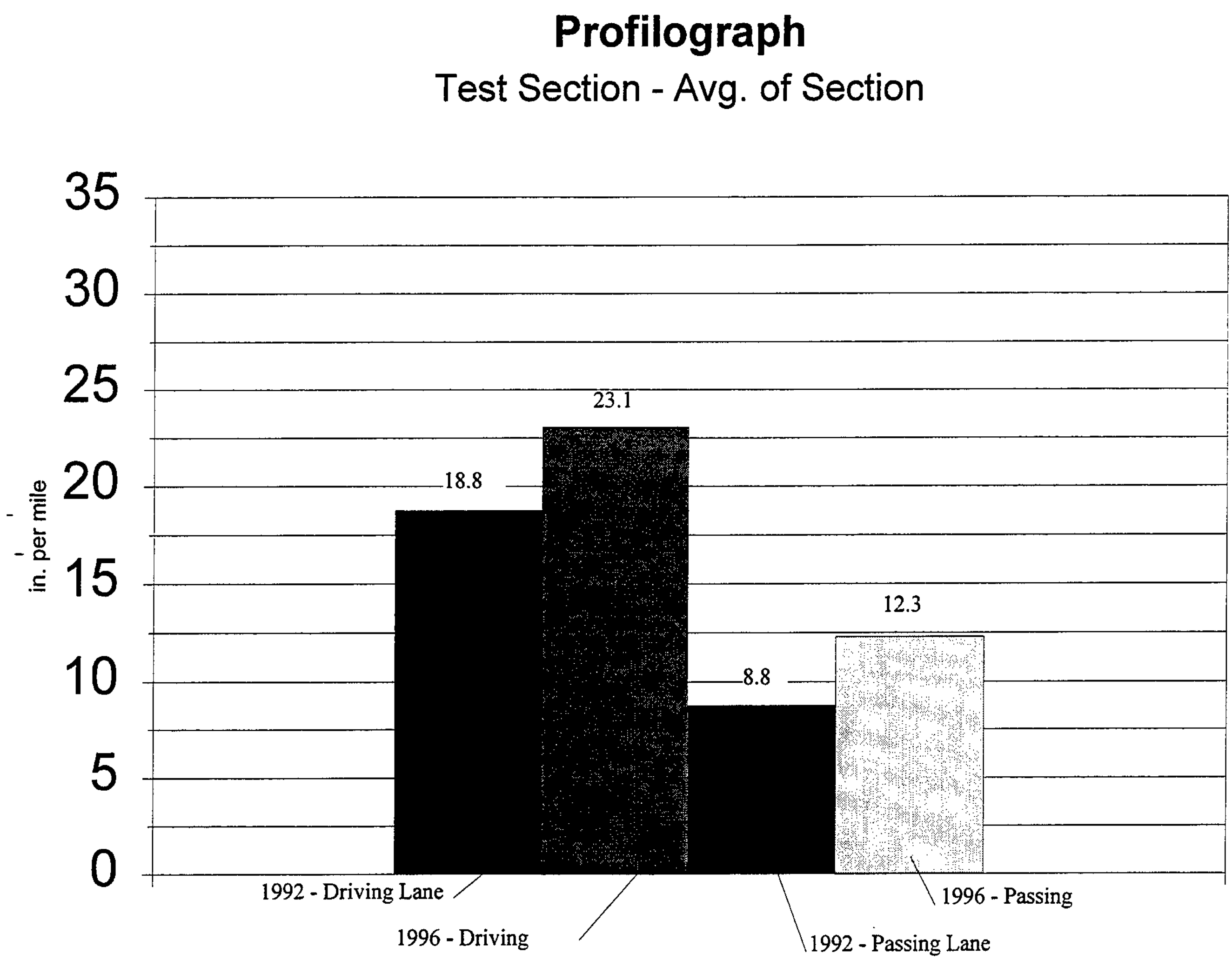

Profilograph
Test Section - Avg. of Section
35
30
25
20
15
10
5
0
in. per mile
18.8
23.1
8.8
12.3
1992 - Driving Lane
1996 - Driving
1992 - Passing Lane
1996 - Passing

Figure 2

2 demonstrates an increase in roughness in both lanes. Driving lane roughness increased by 4.3 inches per mile and the passing lane also increased in roughness by 3.5 inches per mile. These results show that the driving lane and passing lane in the test section are deteriorating at a much more even rate than the control section. This is possibly due to the heavy trucks being placed into the passing lane and evening out the truck distress between the two lanes.

B. Fault Measurements

Faulting of transverse joints is the difference of elevation across a joint. Faulting is caused in part by a buildup of loose materials under the approach slab near the joint or crack as well as depression of the leave slab. The buildup of eroded or infiltrated materials is caused by pumping (free moisture under pressure) due to heavy loadings. The warp or curl upward of the slab near the joint due to moisture and or temperature gradient contributes to the pumping condition. The faulting is determined by measuring the difference in elevation of slabs at joints within the test section. The faulting was measured one foot in from the outside slab edge on all lanes.

The "Highway Pavement Distress Identification Manual" written by the University of Illinois at Urbana Champaign specifies the following for severity levels of transverse joint faulting:

Low - Average faulting within the section is equal to or less than 1.5mm.

Medium - Average faulting within the section is more than 1.5mm but less than 5mm.

High - Average faulting within the section is equal to or more than 5mm.

Concrete faulting was measured using the Georgia fault meter. This meter measures the vertical displacement at the joint using an LVDT (linear variable differential transformer) with a digital readout. Measurements were taken 1 foot in from the shoulder and measured to the nearest tenth of a millimeter. Photo 3 shows the Georgia fault meter prepared to take a measurement across a joint. Figure 3 shows graphically the fault measurements taken from the test section where there was a small increase in the driving lane as well as a small increase in faulting within the passing lane. The test section shows a small increase in both lanes demonstrating that placing truck traffic in the passing lane may help even out the faulting distress between the two lanes. Using the "Highway Pavement Distress Identification Manual" criteria listed above, the faulting with both the test and control section in 1990 would be placed within a medium severity for faulting. The faulting continued to rise within the test section over the four-year period not showing a reduction compared to the control section.

Figure 4 shows the control section (m.p.35 eastbound lanes) faulting in 1992 compared with four years later in 1996. The control section shows an increase in faulting within the driving lane of 46.5%. During the same time period there was no faulting increase within the passing lane. This section (control) did not ask truck drivers to use the passing lane.

C. Cracking and Physical Pavement Distress

Cracking was most severe within the driving lane on both the control section and the test section. The "Highway Pavement Distress Identification Manual" written by the University of Illinois at Urbana Champaign was used to determine the severity of the various distresses encountered within the two sections.

Severity levels for longitudinal cracking according to the distress manual are as follows.

Low - Hairline (tight) crack with no spalling or faulting. A well sealed crack with no visible faulting or spalling.

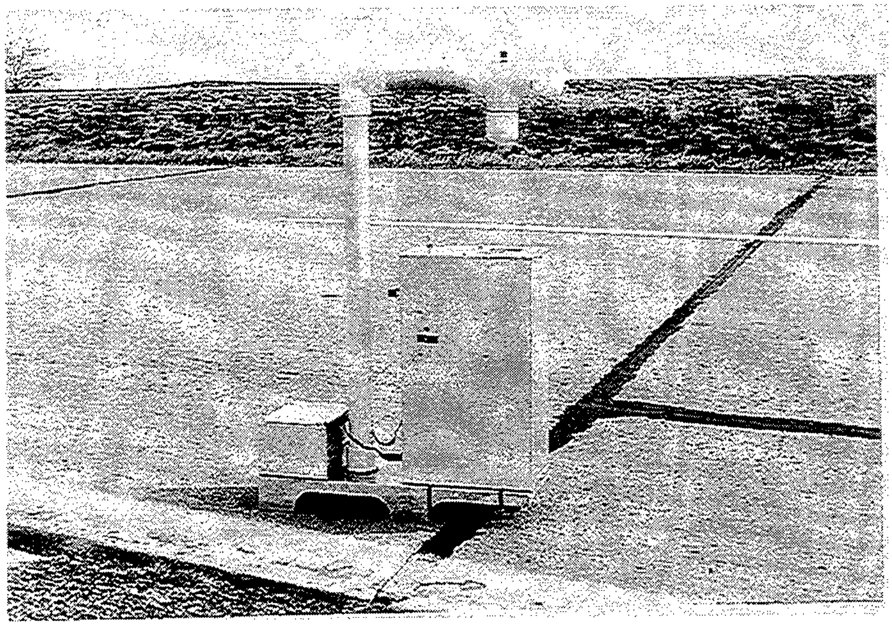


Photo 3 – Fault measurements were taken in mm with the Georgia digital faultmeter.

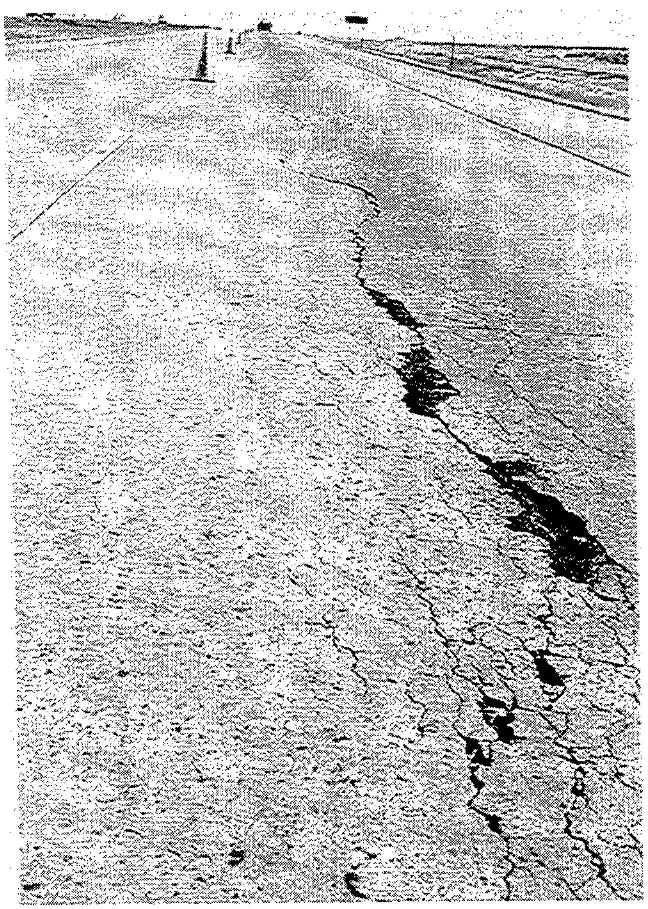
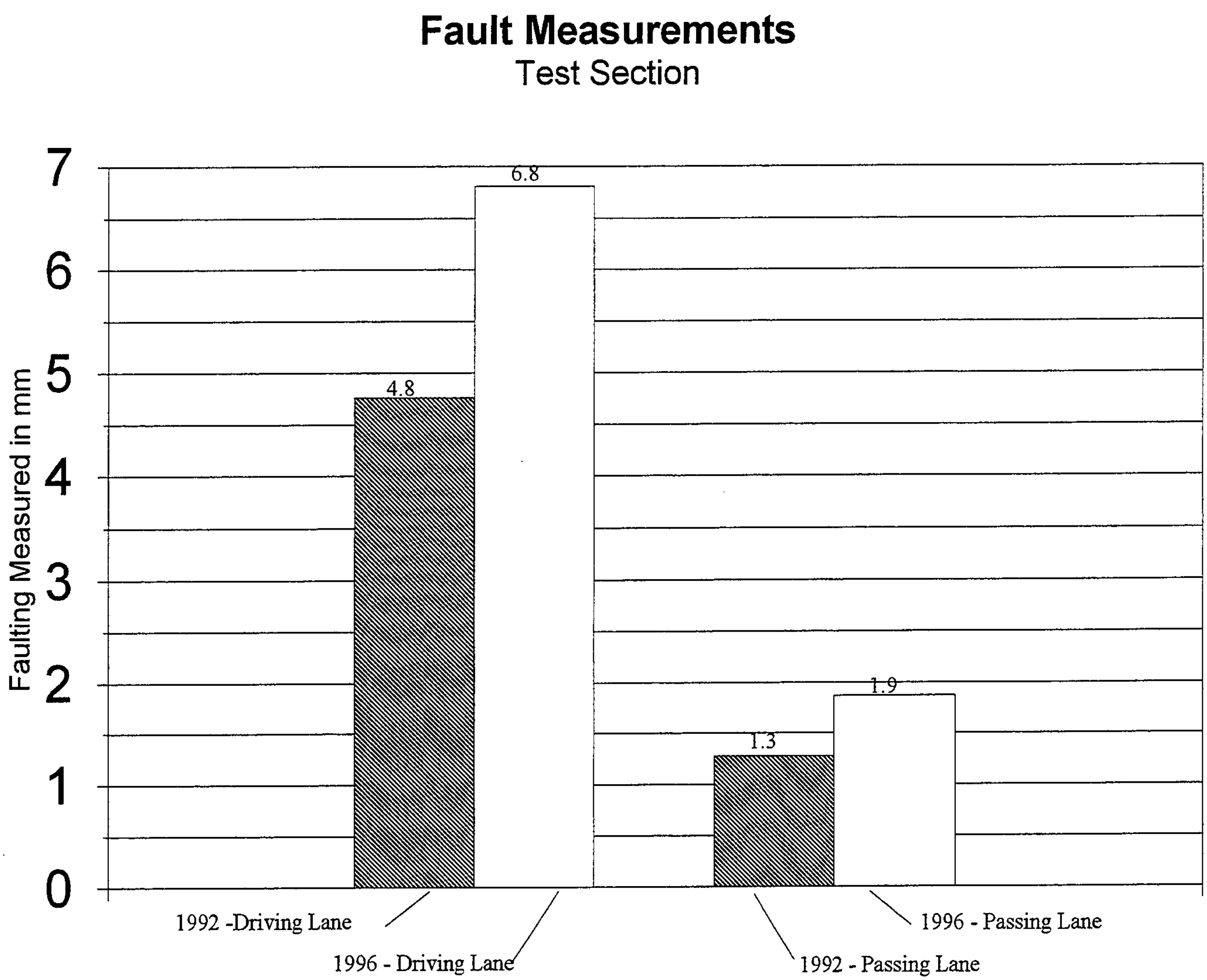


Photo 4 – Control section driving lane with longitudinal cracking and reactive aggregate. Typical in both the control section and the test section.



Fault Measurements
Test Section
Faulting Measured in mm
0
1
2
3
4
5
6
7
4.8
6.8
1.3
1.9
1992 -Driving Lane
1996 - Driving Lane
1992 - Passing Lane
1996 - Passing Lane

Figure 3

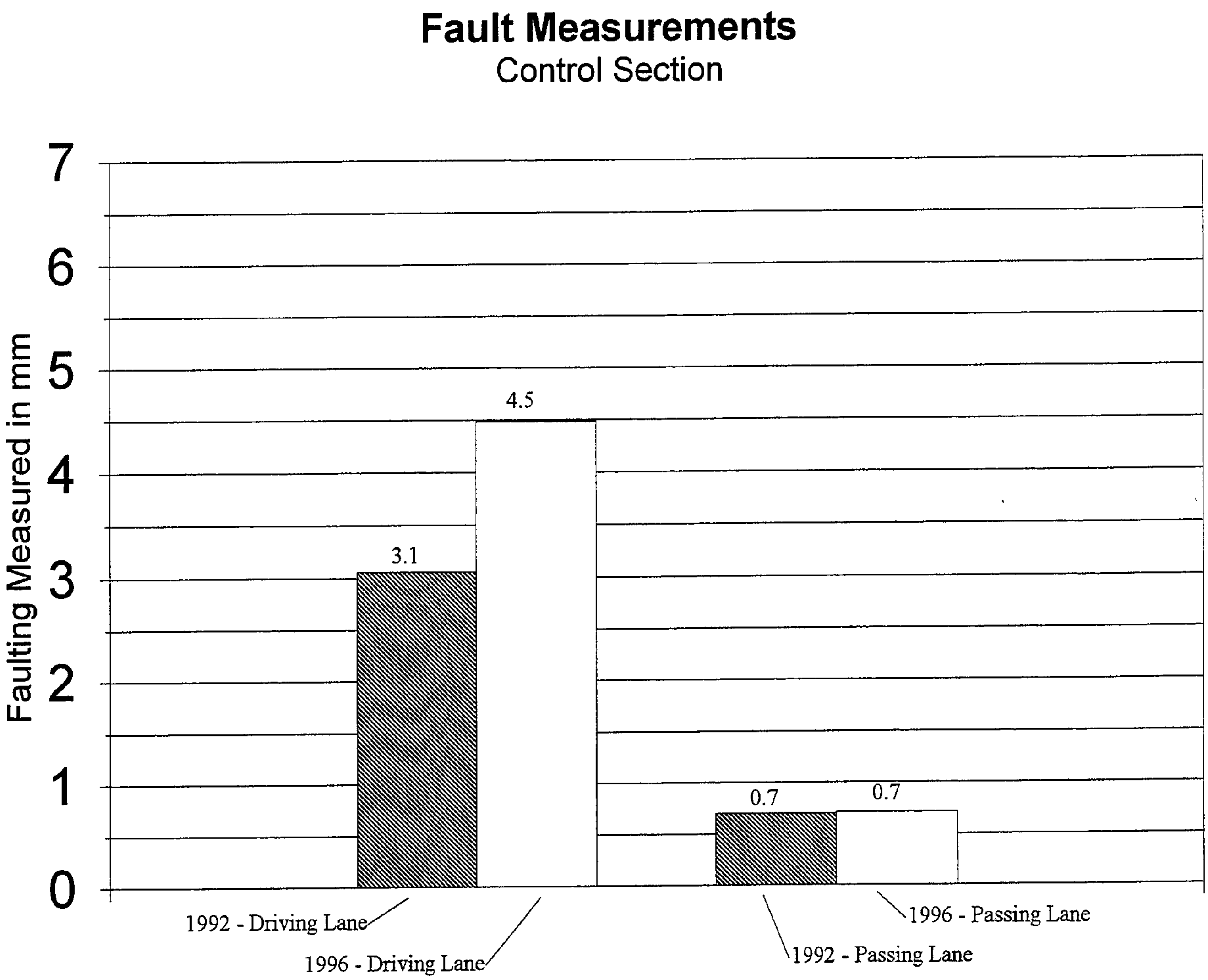

Fault Measurements
Control Section
Faulting Measured in mm
7
6
5
4
3
2
1
0
4.5
3.1
0.7
0.7
1992 - Driving Lane
1996 - Driving Lane
1992 - Passing Lane
1996 - Passing Lane

Figure 4

Medium - Working crack with a moderate or less severity level of spalling and/or faulting less than 1/2 inch (13mm)

High - A crack with width grater than 1 inch (25mm); a crack with a high severity level of spalling; or a crack faulted 1/2 inch (13mm) or more.

Using the above criteria the driving lane within both sections showed a medium severity in longitudinal cracking throughout the site. The passing lane in both sections showed little if any longitudinal cracking. Typical longitudinal cracking can be seen in photo 4. These cracks showed minor increases in length and width over the four-year period. Photo 4 also shows reactive aggregate distress with the driving lane being the most severe in crack widths.

Corner spalling is the ravelling or breakdown of the slab within approximately 2-ft (0.6m) of the corner. A corner spall differs from a corner break in that the spall usually angles downward at about 45 degrees to intersect the joint, while a break extends vertically through the slab. Corner spalling showed a level of low and medium severity within the driving lane on both sections with little or no corner spalling within the passing lane. Changes over the four year period were minor on both test and control sections with no change over the four year period of severity level. The criteria for severity of corner spalling is listed below:

Low - Spall is not broken into pieces. No spalling of cracks exists. Spall is in place and is not loose. Corner spalls with both edges less than 3 inches long will not be counted.

Medium - One of the following conditions exists: Spall is broken into pieces; cracks are spalled; some or all pieces are loose or absent but do not present tire damage or safety hazard. Corner spall is patched.

High - Spall is broken into and/or pieces of the spall have displaced to the extent that they present a tire damage or safety hazard.

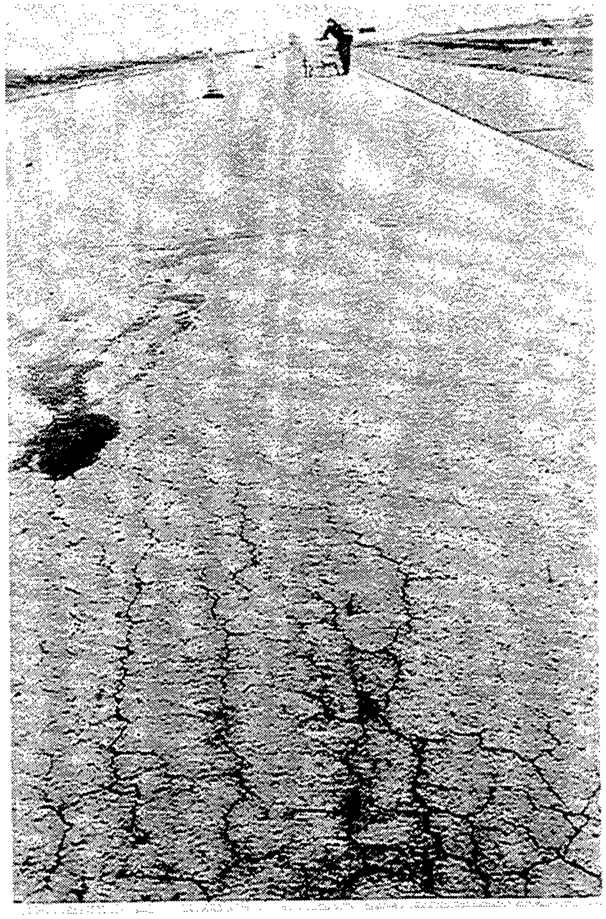


Photo 5 – Reactive aggregate distress can be seen in both lanes however, the driving lane is the most severe.

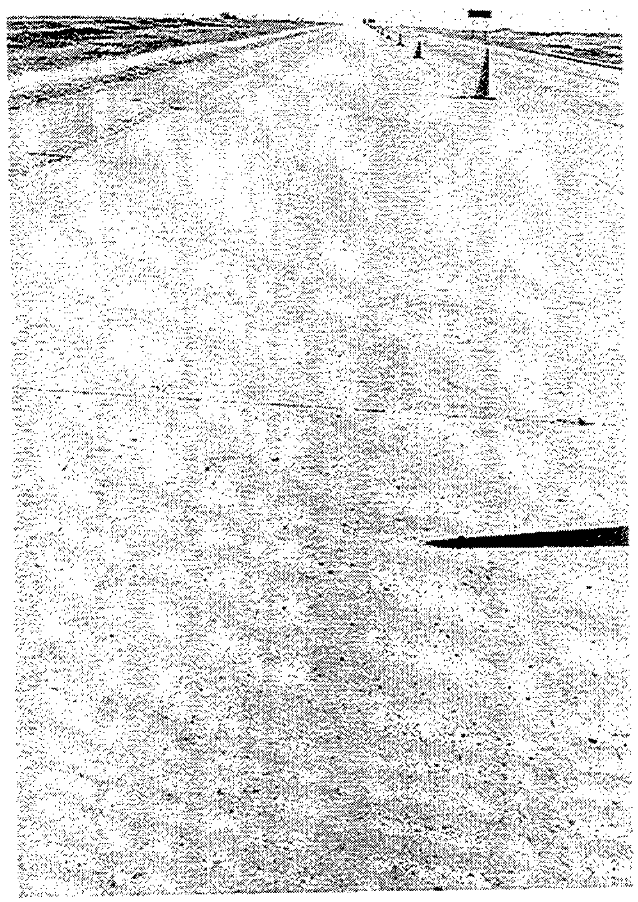


Photo 6 – Control section passing lane showing little distress compared to driving lane. Typical within this area of roadway.

III. TRAFFIC

A. Traffic Lane Usage

One objective of this research project was to determine the effectiveness of experimental lane use signs designed to encourage truck traffic to use the inside-passing lane. Another objective was to determine any detrimental impacts to the flow of traffic caused by the use of the median lane by a greater number of heavy vehicles. Colorado Department of Transportation Staff Traffic performed the following traffic study.

The test section for the traffic evaluation was a twenty-seven mile segment of I-76 from approximately Milepost 39 to Milepost 66 and included the interchanges at Keenesburg, Roggen and Wiggins. This section is classified as a rural interstate. The terrain is generally flat with a few rolling hills.

The project was broken down into two phases. Phase one was prior to the installation of the lane use signs and phase two was after installation. The actual field work for phase one was conducted from November 20, 1989 to December 4, 1989. The field work for phase two was conducted from February 1, 1990 to March 2, 1990. All evaluations were generally conducted between the hours of 8:00 A.M. and 4:00 P.M.

Colorado Department of Transportation Staff Traffic personnel conducted three types of studies. Volume counts, spot speed studies, and conflict studies were performed at various locations in and near the study area. Because of the focus of this study, all vehicles were grouped into five separate classifications. Class I consisted of passenger cars, Class II consisted of pickups and vans, Class III consisted of small buses and r.v.'s, Class IV consisted of trucks (tractor-trailer units or very large single units), and Class V consisted of seasonal farm vehicles. Because of the time period of this study, it was assumed before the study that seasonal farm vehicles may have an impact on the data. However, there was no change in the number of Class V vehicles from phase one to phase two, therefore most of these vehicles were considered to be Class III vehicles and Class V was dropped.

Volume counts were performed at seventeen separate locations. Thirteen sites were located within the boundaries of the test section and four sites were located outside of the test section. The locations were selected to provide data in the vicinity of all interchanges and at approximately two to two and one-half mile intervals on sections where there was no access. Four locations were selected outside of the test section to use as control sites for the after study.

All counts were conducted for one hour. All vehicles passing the test site were manually counted and the classification and the lane of travel were noted. Each direction at each location was counted separately.

Spot speed studies were conducted at the same locations as the volume counts, usually at the same time. As with the volume counts, speed studies were conducted at each location for one hour and each direction was sampled separately. For the speed studies, Classes I and II were combined to facilitate the collection of the data. Again, all vehicles were grouped by the lane in which they were traveling.

Conflict studies were performed at the same locations as the volume counts and the spot speed studies in both phases of this project. Any action by a vehicle that caused another vehicle to change his speed or direction was considered a conflict. The conflict studies at these locations consisted of recording any conflicts that were noted in the one hour time period that the observers were involved in the volume counts. In addition, conflict studies were conducted at all interchanges in the second phase of the project to determine if any conflicts arose from merging or weaving vehicles.

B. Results

For eastbound traffic, the volume counts yielded an average of 184 vehicles per hour (vph) for all vehicles and an average of 40 trucks per hour for the entire section. The maximum volumes occurred at m.p. 56.50 (213 vph average for the two phases) for all vehicles and at m.p. 62.00 (48 vph average) for trucks.

For westbound traffic, the volume counts yielded an average of 177 vehicles per hour for all vehicles and an average of 27 trucks per hour for the entire section. The maximum volumes occurred at m.p. 48.60 (211 vph average) for all vehicles and at m.p. 63.00 (32 vph average) for trucks.

The mix of vehicle types remained fairly constant between the before and after studies. Traffic counts showed that there were a greater number of trucks in the eastbound lanes, both in total numbers and as a percentage of total traffic, than there were in the westbound lanes.

After the signs were installed, the use of the inside-passing lane increased significantly. Utilization of the passing lane increased or remained constant for all classes of vehicles, not just for trucks. The overall average for all vehicles increased from 12.92% to 33.17% for eastbound vehicles and from 12.55% to 28.14% for westbound vehicles. The greatest increases in the utilization of the passing lane occurred in Class IV and Class III. Use of the passing lane by Class IV vehicles increased from 11.64% to 88.53% for eastbound vehicles and from 9.98% to 85.40% for westbound vehicles. Use of the passing lane by Class III vehicles increased from 10.79% to 42.15% for eastbound traffic and from 11.03% to 40.75% for westbound traffic.

The drivers of the Class IV vehicles seemed to eventually settle in to the use of the passing lane approximately ten miles into the test section. In the first ten miles, the percentage of trucks in the median lane varied significantly for both directions. After ten miles, there were less variances in the use of the passing lane by the trucks.

In most cases, compliance with the lane use signs was highest near the posted signs with a trend toward a gradual decrease in utilization of the median until the next sign was reached. As stated earlier, this decrease was more pronounced in the first ten miles of the test section for both directions. Even with these decreases, compliance with the signs remained good. Generally above 75% of all trucks were using the median lane at any given site within the test section.

The increased usage of the passing lane by trucks had no effect on the speeds of the vehicles. The posted speed limit on the test section was 65 mph. Overall, the 85th percentile speeds did not change significantly. For eastbound traffic, the 85th percentile speeds remained at 67 mph for all vehicles and increased from 65 mph to 66 mph for trucks. For westbound vehicles, the 85th percentile speeds remained at 68 mph for all vehicles and increased from 65 mph to 66 mph for trucks. There were greater differences at individual locations but none were directly attributable to changes in lane usage.

Severe incidents were not observed as a part of the conflict study. Most of the conflicts observed involved faster moving vehicles having to slow their speed when approaching a slower moving vehicle in the passing lane. Sometimes the driving lane was also blocked by a slower moving vehicle. However, these incidents were minor. As the speed study showed, trucks were traveling at a speed that was only slightly slower than the speed of all of the vehicles on the highway. Because the speeds were similar and because of the relatively low volume on the existing facility, the potential for conflict was minimal.

Also, there were very few conflicts involving vehicles entering or exiting the highway. Again, because of the low volumes on the mainline, the potential for conflicts appeared to be minimal.

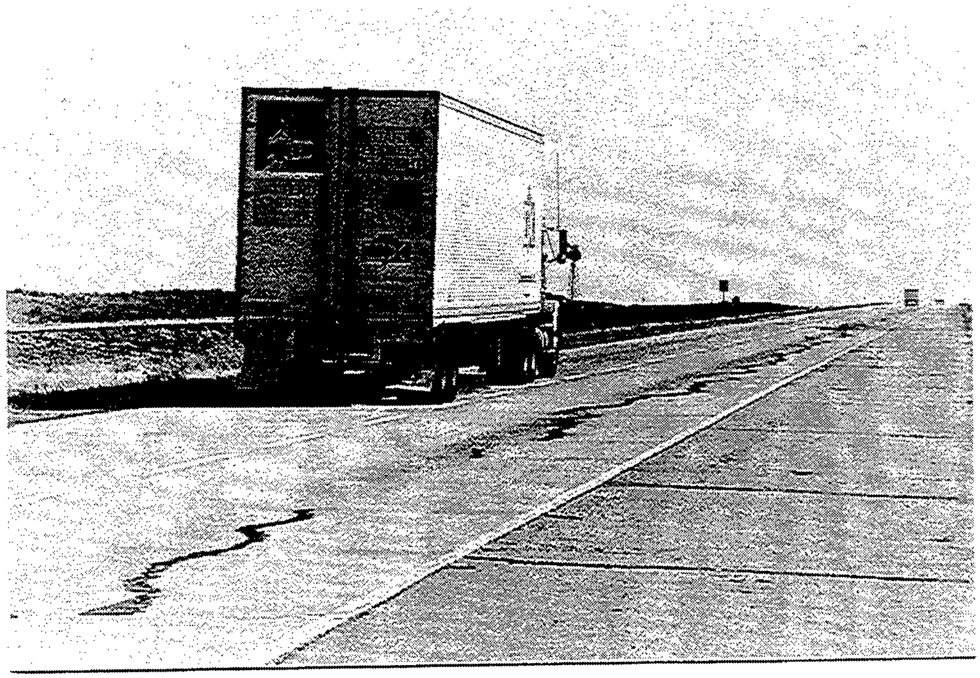


Photo 7 – This photo demonstrates the severity of the longitudinal cracking in the driving lane.

IV. CONCLUSIONS

Thirty years of heavy traffic in the driving lane of I-76 has caused areas of severe distress. Moving heavy trucks into the passing lane and monitoring the changes in distress over a four year period did not show a definite advantage or disadvantage in increasing the life of the pavement in the outside driving lane. However, over the four-year period the distress in the test section appeared to show a balancing effect between the two lanes. This shows that if heavy truck traffic were to be left in the outside driving lane with time the distress would become more severe in the already badly deteriorated lane. The outside driving lane was more severely cracked than the passing lane and showed sections of concrete with blowouts caused by the cracking and the repeated heavy truck traffic. The inside passing lane had no blown out concrete sections and very little cracking. By moving traffic into the inside passing lanes these lanes showed distresses slowly resembling the outside lane and most assuredly gaining life to the outside driving lane by easing the loads within that lane.

Truck usage of the inside passing lane increased significantly when the signs were installed. The overall average for all vehicles increased from 12.92% to 33.17% for eastbound vehicles and from 12.55% to 28.14% for westbound vehicles. The greatest increase in the utilization of the inside passing lane occurred in Class III (small buses and r.v.'s) and Class IV (tractor-trailer units or very large single units). Use of the inside passing lane by Class III vehicles increased from 10.79% to 42.15% for eastbound traffic and from 11.03% to 40.75% for westbound traffic. Use of inside passing lane by Class IV vehicles increased from 11.64% to 88.53% for eastbound vehicles and 9.98% to 85.40% for westbound vehicles.

The increased usage of the inside passing lane by trucks did not show any effect on the speeds of the vehicles and no severe incidents were observed as a part of the conflict study for this area.

V. IMPLEMENTATION

Placing truck traffic into the inside-passing lane appears to be a logical way to temporarily prolong the life of the outside driving lane. On roadways where the driving lane is severely cracked and distressed, placing heavy vehicles on the better conditioned passing lane may help prevent concrete blow outs caused by the heavy trucks and allow the section of roadway to be reconstructed as funds become available.

Looking at traffic data and distress data it is recommended that the truck traffic continues to use the inside passing lane as a primary driving lane to help prolong the life of the driving lane until reconstruction of I-76 can be completed.

REPORTS PUBLICATION LIST
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96-3 The Role of Facing Connection Strength in Mechanically Stabilized Backfill Walls
96-4 Revegetation of MSB Slopes
96-5 Roadside Vegetation Management
96-6 Evaluation of Slope Stabilization Methods (US-40 Berthod Pass) (Construction Report)
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96-8 Determinating Asphalt Cement Content Using the NCAT Asphalt Content Oven
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97-6 IAUAC - (Interim Report)

97-7 Evaluation of Design-Build Practice in Colorado (Pre-Construction Report)

97-8 HBP Pilot Void Acceptance Projects Completed in 1993-1996 (Interim Report)

97-9 QC & QA Projects Constructed in 1996 Under QPM2 Specifications (Fifth Annual Report)

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97-11 Faulted Pavements at Bridge Abutments

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95-2 PCCP Texturing Methods
95-3 Keyway Curb (Contruction Report)
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95-6 Reference Energy Mean Emission Levels for Noise Prediction in Colorado
95-7 Investigation of the Low Temperature Thermal Cracking in Hot Mix Asphalt
95-8 Factors Which Affect the Inter-Laboratory Repeatability of the Bulk Specific Gravity of Samples Compacted Using the Texas Gyratory Compactor
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94-1	Comparison of the Hamburg Wheel-Tracking Device and the Environmental Conditioning System to Pavements of Known Stripping Performance
1-94	Design and Construction of Simple, Easy, and Low Cost Retaining Walls
94-2	Demonstration of a Volumenteric Acceptance Program for Hot Mix Asphalt in Colorado
2-94	The Deep Patch Technique for Landslide Repair
94-3	Comparison of Test Results from Laboratory and Field Compacted Samples
3-94	Independent Facing Panels for Mechanically Stabilized Earth Walls
94-4	Alternative Deicing Chemicals Research
94-5	Large stone Hot Mix Asphalt Pavements
94-6	Implementation of a Fine Aggregate Angularity Test
94-7	Influence of Refining Processes and Crude Oil Sources Used in Colorado on Results from the Hamburg Wheel-Tracking Device
94-8	A Case Study of concrete Deck Behavior in a Four-Span Prestressed Girder Bridge: Correlation of Field Test Numerical Results
94-9	Influence of Compaction Temperature and Anti-Stripping Treatment on the Results from the Hamburg Wheel-Tracking Device
94-10	Denver Metropolitan Area Asphalt Pavement Mix Design Recommendation
94-11	Short-Term Aging of Hot Mix Asphalt
94-12	Dynamic Measurements or Penetrometers for Determination of Foundation Design
94-13	High-Capacity Flexpost Rockfall Fences
94-14	Preliminary Procedure to Predict Bridge Scour in Bedrock (Interim Report)

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93-1 Dense Graded Concrete
93-2 Research 92- Reality and Vision, Today and Tomorrow (Status Report)
93-3 Investigation of the Modified Lottman Test to Predict the Stripping Performance of Pavements in Colorado
93-4 Lottman Repeatability
93-5 Expert System for Retaining Wall System Phase I
93-6 Crack Reduction Pavement Reinforcement Glasgrid
93-7 A Case Study of Elastic Concrete Deck Behavior in a Four Panel Pre-stressed Girder Bridge Finite Element Analysis
93-8 Rehabilitation of Rutted Asphalt Pavements (Project IR-25-3(96)
93-9 Cold Hand Patching
93-10 Ice Detection and Highway Weather Information Systems, FHWA Experiment Project No. 13
93-11 Comparison of 1992 Colorado Hot Mix Asphalt With Some European Specification
93-12 Curtain Drain
93-13 Type T Manhole (Experimental Feature)
93-14 Interim Report for the HBP QA/QC Pilot Projects Constructed in 1992
93-15 SHRP Seasonal Monitoring Program in Delta
93-16 DOT Research Management Questionnaire Response Summary
93-17 Inservice Evaluation of Highway Safety Devices
93-18 Courtesy Patrol Pilot Program
93-19 I-70 Silverthorne to Copper Mountain: A History of Use of European Testing Equipment
93-20 Analytical Simulation of Rockfall Prevention Fence Structures
93-21 Investigating Performance of Geosynthetic-Reinforced Soil Walls
93-22 Influence of Testing Variables on the Results from the Hamburg Wheel-Tracking Device
93-23 Determining Optimum Asphalt Content with the Texas Gyratory Compactor

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92-1 Colorado Department of Transportation Asphalt Pavement White Paper
92-2 Expansive Soil Treatment Methods in Colorado
92-3 Gilsonite An Asphalt Modifier
92-4 Avalanche Characteristics and Structure Response - East Riverside Avalanche Shed Highway 550, Ouray County Colorado
92-5 Special Polymer Modified Asphalt Cement - Interim Report
92-6 A User Experience with Hydrain
92-7 Chloride Content Program for the Evaluation of Reinforced Concrete Bridge Decks
92-8 Evaluation of Unbonded Concrete Overlay
92-9 Fiber Pave, Polypropylene Fiber
92-10 Description of the Demonstration of European Testing Equipment for Hot Mix Asphalt Pavement
92-11 Comparison of Results Obtained From the French Rutting Tester With Pavements of Known Field Performance
92-12 Investigation of the Rutting Performance of Pavements in Colorado
92-13 Factors That Affect the Voids in the Mineral Aggregate In Hot Mix Asphalt
92-14 Comparison of Colorado Component Hot Mix Asphalt Materials With Some European Specifications
92-15 Investigation of Premature Distress in Asphalt Overlays on IH-70 in Colorado

91-1 Dynamic Measurements on Penetrometers NEVER PUBLISHED
91-2 Geotextiles in Bridge Abutments NEVER PUBLISHED
91-3 Industrial Snow Fence vs. Wooden Fences
91-4 Rut Resistant Composite Pavement Design (Final Report)
91-5 Reflective Sheeting (Final)
91-6 Review of Field Tests and Development of Dynamic Analysis Program for CDOH Flexpost Fence
91-7 Geotextile Walls for Rockfall Control (CANCELED)
91-8 Fly Ash in Structural Concrete
91-9 Polyethylene Pipes for Use as Highway Culverts
91-10 Ice-Detection System Evaluation
91-11 Evaluation of Swareflex Wildlife Warning Reflectors
91-12 Analysis and Design of Geotextile-Reinforced Earth Walls, Vol. III Parametric Study and Preliminary Design Method