Evaluation of I-75 Lane Closures

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A spot pavement replacement and joint sealing project on I-75 in southern Kentucky during the 1986 construction season involved numerous lane closures. Traffic congestion caused by heavy volumes and late merges resulted in the use of the following traffic control devices to supplement standard lane closure devices: variable message signs, supplemental lane closure warning signs, and rumble strips placed in the lane to be closed in advance of the taper. Because the devices were not typical applications for work zones and because of the potential for applications at other sites, an evaluation study was conducted. Results showed a decrease in the percentage of traffic in the lane to be closed with each successive traffic control device in addition to the standard lane closure devices. There was a general decrease in speeds as traffic approached the taper. The percentage of trucks in the lane to be closed was lower than the percentage in the open lane when the closure was a left lane. Hourly traffic volumes observed in this study (800 to 1,300 vph) did not appear to influence the percentage of traffic in the lane to be closed. The percentage of trucks in both lanes (8.5 to 14.7 percent) did not influence the percentage of traffic in the lane to be closed either. Recommendations from the study included the following: (a) supplemental signs for all long-term closures on high-volume, high-speed four-lane roadways, (b) variable message signs when one-way hourly volumes exceed 1,000 (ADT exceeds 20,000), and (c) application of rumble strips if other devices do not reduce late merges and there is excessive congestion.

Construction and maintenance work zones have traditionally been hazardous locations within the highway environment. Safety in work zones has been recognized as a significant problem for several years, and the subject has received additional attention with the shift from construction of new facilities to the improvement or rehabilitation of existing facilities. With recent increases in the volume of traffic and changes in the compositions of the traffic streams, however, congestion on some highway sections has increased, and there is a greater potential for accidents. Several studies have shown that accident rates within construction or maintenance work zones are higher than for similar periods before work zones were established (*1–3*). Among the many factors cited as reasons for the increase in accident rates are inappropriate use of traffic control devices, poor traffic management, inadequate layout of the overall work zone, and a general misunderstanding of the unique problems associated with construction or maintenance work zones.

The closure of a lane on a four-lane high-speed facility during construction or maintenance activity presents potential safety problems. Lane closure problems are related to changes in the driving environment that require the driver to make adjustments in order to travel through a work zone safety. On high-volume four-lane facilities, problems occur when two lanes of traffic must be warned sufficiently in advance so that motorists may travel safety through the transition zone of merging two lanes into one lane at the work site. Frequently, there are vehicles that fail to merge to the open lane, at situation that leads to congestion and erratic maneuvers at the beginning of the taper.

The *Manual on Uniform Traffic Control Devices* (*4*) provides details on standard applications for lane closures, and those applications appear to be adequate for most situations. However, as volumes increase and geometric conditions place additional constraints on the flow of traffic at a lane closure, consideration should be given to additional traffic control devices. The effectiveness of variable message signs has been evaluated previously, and the results were increased advance lane change activity, smoother lane change profiles, and significantly fewer lane changes near the taper (*5*). As a result of that study, the following suggestions for additional research were made: use of arrows in barricade design, multiple variable message signs, audible signals such as rumble strips, and combined use of symbols and words on variable message signs (*5*).

A project on I-75 in Whitley and Laurel counties, Kentucky, during the 1986 construction season involved numerous lane closures to accommodate spot pavement replacement and joint sealing. Traffic congestion caused by heavy volumes and failure to adhere to the traffic control messages resulted in a decision by the Kentucky Department of Highways to use additional traffic control devices to encourage proper merging for a smoother flow of traffic through the lane closures. Additional traffic control devices used in this case included supplemental signs, variable message signs, and rumble strips. Because these additional devices were not typical applications for work zones, it was decided that their effectiveness should be evaluated.

DATA COLLECTION

Data were collected at lane closures on I-75 in Whitley and Laurel counties between June 6, 1986, and August 8, 1986. Data collection periods of 6 hr each on five Friday afternoons and four Sunday afternoons were included. Table 1 is a summary of data collection dates, locations, and traffic control conditions for each of the data collection periods. All data were collected from 11:00 a.m. to 5:00 p.m. on Fridays and from 12:00 noon to 6:00 p.m. on Sundays.

Because the objective of this study was to determine whether supplemental traffic control devices could be used at work zones to improve the flow of traffic through lane closures, it was necessary to add devices to the standard control devices by

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TABLE 1 DATA COLLECTION DATES, LOCATIONS, AND TRAFFIC CONTROL CONDITIONS

Date	Lane Closure Location	Traffic Control Conditions
6/06/86	I-75 SB, MP 42.2	Standard left-lane closure traffic control devices
6/08/86	I-75 NB, MP 27.2	Standard right-lane closure traffic control devices
6/13/86	I-75 SB, MP 42.2	Standard left-lane closure traffic control devices and variable message sign placed 1.8 mi before lane closure
6/15/86	I-75 NB, MP 27.2	Standard right-lane closure traffic control devices and variable message sign placed 1.25 mi before lane closure
6/20/86	I-75 SB, MP 42.2	Standard left-lane closure traffic control devices, variable message sign placed 2 mi before lane closure, and supplemental construction zone signs placed 5, 4, 3, and 2 mi before lane closure
6/22/86	I-75 NB, MP 30.1	Standard left-lane closure traffic control devices, variable message sign placed 0.9 mi before lane closure, and supplemental construction zone signs placed 5, 4, 3, and 2 mi before lane closure
7/11/86	I-75 SB, MP 46.4	Standard left-lane closure traffic control devices, variable message sign placed 2 mi before lane closure, supplemental construction zone signs placed 5, 4, 3, and 2 mi in advance of lane closure, and rumble strips placed 1.5, 1.0, 0.6, 0.3, and 0.1 mi before lane closure
7/27/86	I-75 NB, MP 17.9	Standard left-lane closure traffic control devices, variable message sign placed 1.9 mi before lane closure, and supplemental construction zone signs placed 5, 4, 3, and 2 mi before lane closure
8/08/86	I-75 NB, MP 14.2	Standard left-lane closure traffic control devices, variable message sign placed 1.9 mi before lane closure, supplemental construction zone signs placed 5, 4, 3, and 2 mi in advance of lane closure, and rumble strips placed 1.5, 1.0, 0.6, 0.3, and 0.1 mi before the lane closure

NOTE: NB = northbound, SB = southbound, MP = milepoint.

an incremental process. This required selection of sites at which the lane closure would exist for a long enough time to permit addition of the supplemental devices and data collection before the closure had to be moved. Obvious constraints on these requirements were construction schedules and holiday periods. It was undesirable to extend the time of lane closures from the standpoint of prolonged congestion and increased accident potential. Therefore some variability in the data was expected because of the inability to evaluate all increments of supplemental traffic control at the same location. Geometric constraints included vertical curves, horizontal curves, and interchange ramps.

As presented in Table 1, data collection included four days for southbound traffic and five days for northbound traffic. For southbound traffic, one site (I-75 at milepoint 42.2) was used for the first three lane closure traffic control conditions, and another site (I-75 at milepoint 46.4) was used for the fourth lane closure condition. The first lane closure condition consisted of the standard left-lane closure traffic control devices, as shown in Figure 1. To evaluate the effect of lane closure advance warning devices, it was necessary to station observers at four positions in advance of the closed lane. For the standard lane closure control condition, observers were positioned at the following points with respect to data collection needs:

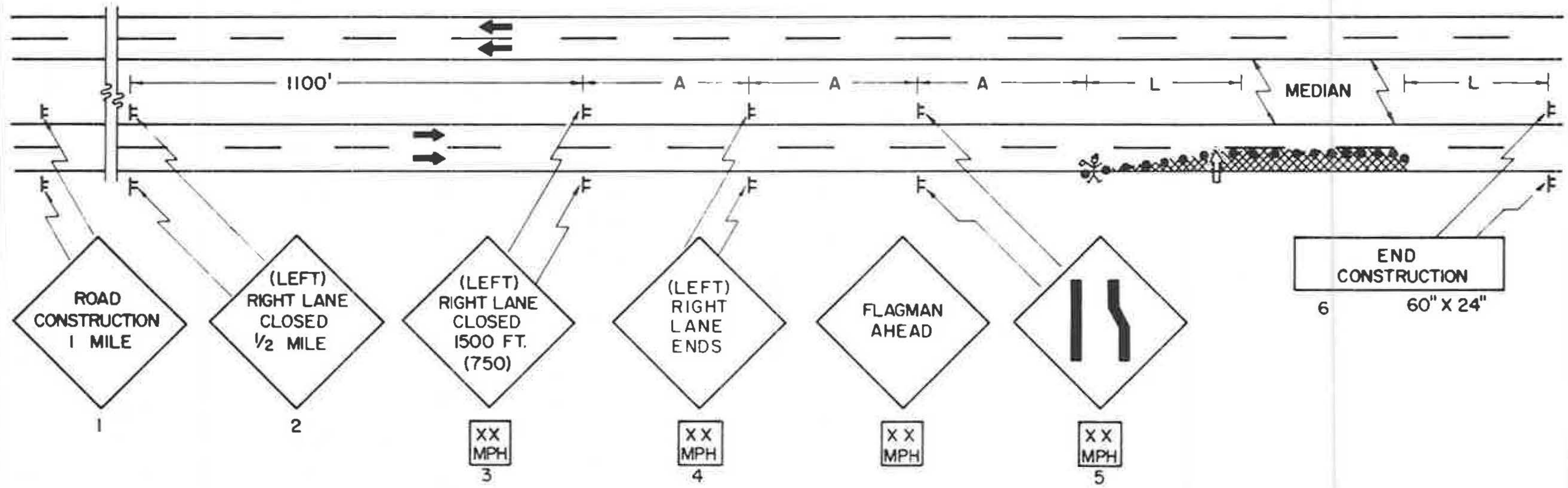
- Before construction zone signs, where free-flowing traffic could be observed;
- At the point where the variable message sign was to be placed;
- Between the variable message sign position and the beginning of the taper; and
- At the beginning of the taper.

Several observation points were necessary to monitor the effect of various traffic control conditions on lane distributions and speeds. Data also were collected to represent total volumes and percent trucks.

Data were collected on June 6, 1986, to document lane distribution and speed conditions for standard lane closure traffic control devices. On the following Friday (June 13, 1986), data were collected at the same observation points with the variable message sign (message was Merge Right, with an arrow progressively moving to the right) placed 1.8 mi before the lane closure. Sight distance requirements made it necessary to place the variable message sign either 1.8 mi before or very near to the beginning of the taper and the standard arrow board. The third data collection date was June 20, 1986, and this same lane closure at milepoint 42.2 on I-75 was modified by adding signs 5, 4, 3, and 2 mi before the closure indicating that the left lane was closed. These supplementary signs were in addition to standard lane closure devices and the variable message sign 1.8 mi before the taper. The fourth traffic control condition was the addition of sets of rumble strips 1.5, 1.0, 0.6, 0.3, and 0.1 mi before the beginning of the taper. Because the lane closure had been moved before the fourth day of data collection, it was necessary to delay additional data collection in the southbound direction until July 11, 1986. The site for evaluation of the rumble strips was located at milepoint 46.4 on I-75, and there were geometric constraints in the form of both vertical and horizontal curvature that may have influenced the lane distribution and speed data.

Rumble strips used before the lane closure consisted of eight strips per set, placed with 24 in. between strips. As noted previously, the strips were installed 1.5, 1.0, 0.6, 0.3, and 0.1 mi before the taper in the lane to be closed. The strips were made of a hard plastic-vinyl material, with dimensions of $^1/_2$ in. × 4 in. × 23$^3/_4$ in. Each set required 48 strips, or 240 strips for five sets. The installation process included the following steps:

- Preparation of the surface by brushing,
- Application of solvent cement to the back of the strip,
- Placement of the strip on the pavement,
- Application of pressure to the strip so that a coating of cement was deposited on the pavement,
- Removed of the strip from the pavement for approximately 30 sec so that the cement was exposed to the air to dry, and



APPLICATION

This drawing applies to lane closure of shoulder or median lanes on two direction multi-lane highways with medians over six (6) feet in width.

SIGNING AND SPACING TABLE

NORMAL POSTED SPEED LIMIT	"L" FT.	SIGNS REQUIRED	SIGN SIZE (1 THRU 5)	SPEED ADVISORY	ADVISORY SPEED PLATE SIZE	"A" FT.
55 and above	900	1 thru 6	48"X 48"	45 ①	24"X 24"	500
45 to 50	600	3 thru 6	48"X 48"	35 ①	24"X 24"	500
35 to 40	440	3 thru 6	48"X 48"	25 ①	24"X 24"	250
Less than 35	360	3 thru 6	48"X 48" or 36"X 36"	None Req.①	24"X 24"	250

① Or as directed by the Engineer

LEGEND

- Portable Flashing Arrow
- Flagman
- Sign
- L Length of Transition
- ● CHANNELIZATION DEVICES
  - Cones
  - Drums
  - Type II Barricades
  - Tubular Markers

Traffic Cones, Tubular Markers, Drums or Type II Barricades shall be maintained throughout the entire length of the immediate construction area. Spacing of Channelization Devices shall not exceed forty (40) ft. throughout the work site and the transition zone. (Note: Skip lines on pavement are normally forty (40) feet from begining of line to begining of line.)

The Engineer may require the use of Drums or Type II Barricades in lieu of Cones or Tubular Markers if the closure time exceeds four (4) days.

The signs shall be moved behind the ditch line, and made inaccessible to the view of traffic or covered, at any time the lane is not physically closed.
The portable flashing arrow shall be required when the normal posted speed limit is greater than 45 MPH. At speeds less than 45 MPH, a flagman may be used in lieu of the portable flashing arrow as specified in the plans or as directed by the Engineer. When a flagman is used, the "Flagman Ahead" sign shall be substituted for the "(Left) Right Lane Ends Sign." All traffic control devices required on this drawing shall conform to the requirements shown on the current edition of Standard Drawing No. TSC 260, TSC 270, and to the Department's "Manual On Uniform Traffic Control Devices". Use "750 Ft." on sign No. 3 when the normal posted speed limit is 40 miles per hour or less.

Sign spacing may be modified or adjusted slightly to fit the physical conditions encountered such as driveways, approach roads, etc. Such modifications shall have the approval of the Engineer.

When approach roads and intersecting streets are encountered, some additional signing may be required on these roads and streets which is not shown on this drawing. Such signing shall conform to the requirements of the Department's "Manual On Uniform Traffic Control Devices" as directed by the Engineer.

KENTUCKY
DEPARTMENT OF HIGHWAYS

LANE CLOSURE
CASE III

STANDARD DRAWING No. TSC 210-03

SUBMITTED

APPROVED

STATE HIGHWAY ENGINEER

FIGURE 1 Standard lane closure traffic control devices.

• Application of pressure to the strip again to bond it to the pavement.

The rumble strips used in the installation were purchased from Astro Optics, and the solvent cement (Type SC-1958) was produced by the H. B. Fuller Company.

After installation, traffic was allowed to pass over the strips after about 2 hr, even though the solvent cement remained soft and flexible. The solvent cement proved to be a very good adhesive for application of the rumble strips. The cement was relatively easy to apply with caulking guns. It remained somewhat flexible for several hours yet sufficiently bonded the strips to the pavement, and the strips were relatively easy to remove. After removal of the strips, the cement remained on the pavement, but it was thin enough so that there was no noticeable noise when vehicles passed over it. At the northbound installation of rumble strips, the number missing after 9 days was 12 of the 240 (5 percent). This loss of a few strips did not appear to diminish the effectiveness of the installation.

The first data collection at a northbound lane closure was on June 8, 1986, at milepoint 27.2. Traffic control at this location was a standard right lane closure. That same location was used again on June 15, 1986, with the addition of the variable message sign 1.25 mi before the closure. However, on the third Sunday of data collection, it was necessary to move to a new site at milepoint 30.1 because the closure at milepoint 27.2 had been removed. This resulted in data collection at a different location with supplemental signs at 5, 4, 3, and 2 mi before the closure. The difficulty of evaluating those signs was complicated because the observation points had to be located very near an interchange ramp.

Because roadway geometrics had complicated the evaluation process for determining the potential impact of adding rumble strips to the three previous control conditions, it was decided that data should be collected at a site with and without rumble strips. That required two additional data collection periods with all other traffic control conditions in place on the first date and rumble strips added to the existing control devices on the second date. The final two data collection dates were July 27 and August 8, 1986. Again because of unanticipated construction scheduling problems, data could not be collected at the same site for two consecutive weeks at a northbound site. However, there did not appear to be major geometric differences that would prevent a comparison of those two lane closures with and without rumble strips.

RESULTS

The primary measure of effectiveness for evaluating the various traffic control alternatives was percentage of traffic remaining in the lane to be closed. As noted previously, data were collected at the following points before the lane closure:

- Before the construction zone signs,
- At the variable message sign or where it was to be placed,
- Between the variable message sign and the beginning of the taper, and
- At the beginning of the taper.

Other data collected included average speeds at the observation points in advance of the construction zone and at the observation point between the variable message sign and the beginning of the taper. Percent trucks and average hourly traffic volumes were also tabulated for each of the observation points. Summaries of the various types of data collected at southbound and northbound sites are presented in Tables 2 and 3, respectively.

TABLE 2 SUMMARY OF DATA COLLECTED AT SOUTHBOUND LANE CLOSURES

Date	Location	Traffic Control Conditions	Data Collection Point	Distance From Taper (mi)	Average Speed (mph)	Percent of Traffic in Lane To Be Closed	Percent Trucks in Lane To Be Closed	Average Percent Trucks (both lanes)	Average Hourly Traffic (both lanes)
6/06/86	I-75 SB, MP 42.2	Standard left-lane closure	Free-flowing	3.6	60.1	35.8	4.9	12.1	913
			Free-flowing	1.8		29.0	5.8	12.8	808
			Intermediate	0.9	58.2	35.7	7.9	12.2	953
			500 ft before taper	0.1		14.9	9.6	11.3	967
			At taper	0		3.7	9.2	11.3	967
6/13/86	I-75 SB, MP 42.2	Standard left-lane closure and variable message sign	Free-flowing	3.6	60.8	50.8	4.9	11.7	1,042
			Free-flowing	1.8		20.3	5.2	11.2	1,096
			Intermediate	0.9	60.3	23.6	7.4	11.2	1,018
			500 ft before taper	0.1		11.6	17.3	11.9	1,068
			At taper	0		3.2	9.0	11.9	1,068
6/20/86	I-75 SB, MP 42.2	Standard left-lane closure, variable message sign, and supplemental signs	Free-flowing	3.6	62.4	37.0	4.1	10.6	1,095
			Free-flowing	1.8		17.7	5.8	10.6	1,104
			Intermediate	0.9	61.1	21.7	8.0	10.5	1,076
			500 ft before taper	0.1		10.4	5.3	9.6	1,096
			At taper	0		3.0	1.5	9.6	1,096
7/11/86	I-75 SB, MP 46.4	Standard left-lane closure, variable message sign, supplemental signs, and rumble strips	Free-flowing	8.1	62.6	37.7	6.2	11.2	1,082
			Free-flowing	2.1		24.0	7.2	10.9	1,075
			Intermediate (at rumble strips)	1.25	57.2	26.2	7.8	11.6	1,030
				0.8	55.5	22.8	3.9	10.6	1,013
				0.45	48.4	24.9	2.5	11.2	952
				0.2	51.6	11.4	5.3	10.4	1,114
			500 ft before taper	0.1		7.8	3.6	9.2	1,063
			At taper	0		2.1	3.0	9.2	1,063

NOTE: SB = southbound, MP = milepoint.

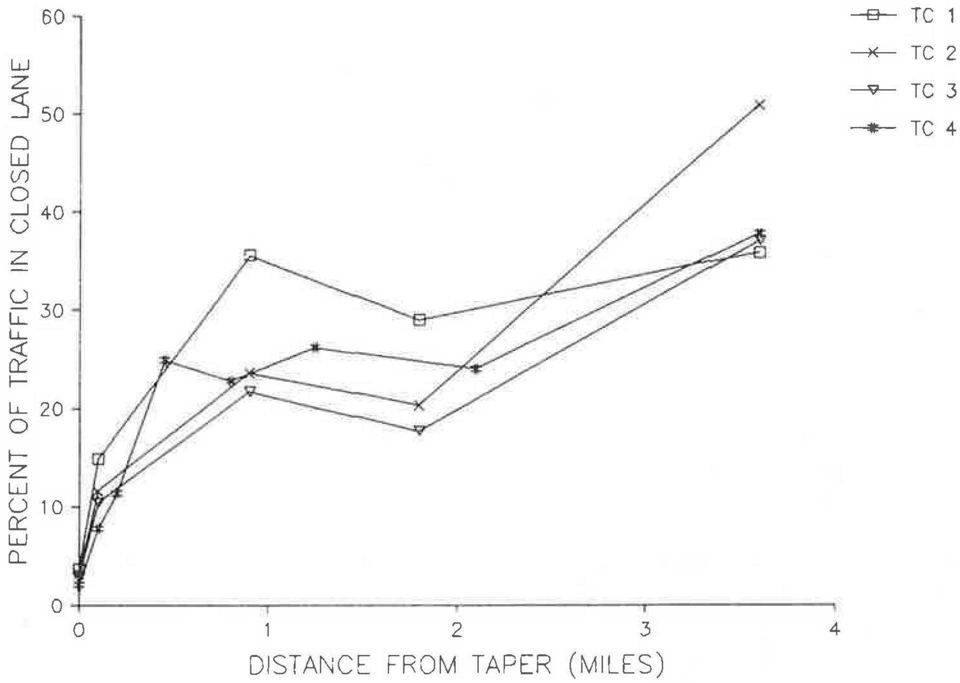
TABLE 3 SUMMARY OF DATA COLLECTED AT NORTHBOUND LANE CLOSURES

Date	Location	Traffic Control Conditions	Data Collection Point	Distance From Taper (mi)	Average Speed (mph)	Percent of Traffic in Lane to be Closed	Percent Trucks in Lane to be Closed	Average Percent Trucks (both lanes)	Average Hourly Traffic (both lanes)
6/06/86	I-75 NB, MP 27.2	Standard right-lane closure	Free-flowing	1.8	64.8	59.8	14.5	11.7	1,005
			Free-flowing	1.25		61.9	12.4	10.2	1,083
			Intermediate	0.5	61.1	59.1	12.9	12.0	1,075
			500 ft before taper	0.1		21.9	9.1	11.3	1,047
			At taper	0		6.7	5.9	11.3	1,047
6/15/86	I-75 NB, MP 27.2	Standard right-lane closure and variable message sign	Free-flowing	1.8	61.0	55.8	12.2	9.4	1,133
			Free-flowing	1.25		19.3	14.6	9.6	1,085
			Intermediate	0.5	54.2	19.3	15.6	9.6	1,139
			500 ft before taper	0.1		10.9	13.1	8.9	1,117
			At taper	0		6.9	12.4	8.9	1,117
6/22/86	I-75 NB, MP 30.1	Standard left-lane closure, variable message sign, and supplemental signs	Free-flowing	3.5	61.9	35.6	8.7	9.8	1,253
			Free-flowing	0.9		20.3	7.8	10.2	1,224
			Intermediate	0.5	54.0	9.9	10.7	10.2	1,299
			500 ft before taper	0.1		5.6	12.9	8.5	1,273
			At taper	0		3.3	11.6	8.5	1,273
7/27/86	I-75 NB, MP 17.9	Standard left-lane closure, variable message sign, supplemental signs	Free-flowing	5.9	57.6	38.3	4.3	10.0	1,018
			Free-flowing	1.9		33.0	3.6	9.5	1,059
			Intermediate	1.1	57.1	25.6	6.0	9.7	1,064
			500 ft before taper	0.1		11.0	4.3	8.7	1,070
			At taper	0		3.0	6.3	8.7	1,070
8/08/86	I-75 NB, MP 14.2	Standard left-lane closure, variable message sign, supplemental signs, and rumble strips	Free-flowing	5.8	63.7	33.6	8.2	12.7	882
			Free-flowing	2.2		30.3	5.3	11.8	1,015
			Intermediate (at rumble strips)	1.4	58.6	22.3	9.2	14.7	975
				0.8	57.4	23.2	8.2	13.8	1,006
				0.4	61.0	18.9	7.6	11.1	995
				0.2	57.6	8.9	11.4	13.2	889
			500 ft before taper	0.1		4.1	9.0	10.9	950
			At taper	0		0.1	6.4	10.9	950

NOTE: NB = northbound, MP = milepoint.

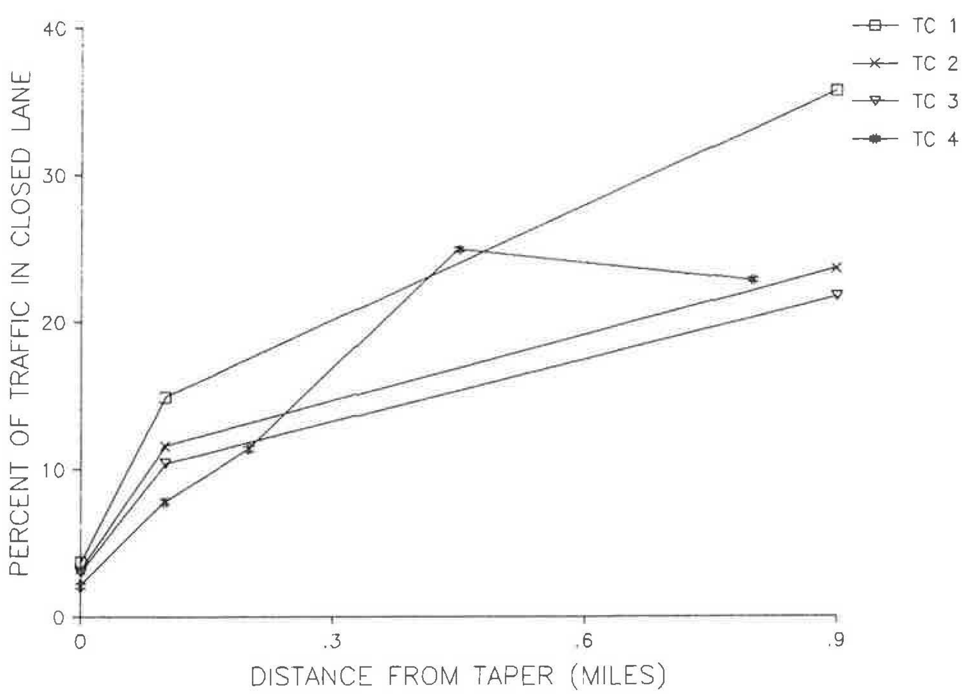
For southbound sites (Table 2), the data generally indicated a decreasing percentage of traffic in the lane to be closed as the distance to the taper decreased. When the various traffic control conditions were compared, a decrease was also seen in the percentage of traffic in the closed lane with the addition of traffic control devices beyond the standard lane closure devices. The data that show the relationship between percent of traffic in the lane to be closed and the distance from the taper are presented graphically in Figure 2. The general trend over approximately 3.5 mi before the taper indicated the effectiveness of various traffic control devices. Specifically, it may be noted that the addition of a variable message sign (Merge Right or Left with arrow) has a positive effect on decreasing the percentage of traffic in the lane to be closed. For example, the percentage of traffic in the lane to be closed decreased from 14.9 percent to 11.6 percent at 0.1 mi before the taper. If the data in Table 2 are examined further, it may be seen that the addition of supplemental advance warning signs reduced the percentage of traffic in the closed lane to 10.4 percent at 0.1 mi in advance. The effect of adding a variable message sign and then supplemental construction zone warning signs to the standard lane closure signs could be evaluated without questioning the results because data were collected at the same lane closure site. The addition of rumble strips to the standard lane closure signs, variable message sign, and supplemental signs, however, was complicated because data had to be collected at a new lane closure site. The site at which rumble strips were installed included both horizontal and vertical curvatures, which may have resulted in the greater probability of a higher percentage of vehicles being in the closed lane. The results presented in Table 2 show 7.8 percent of the traffic in the closed lane (at 0.1 mi before the taper) with rumble strips added as compared to 10.4 percent without rumble strips but with the other three traffic control conditions. To better show the effect of various traffic control conditions within 1 mi of the taper, Figure 3 was prepared. That figure allows comparisons to be made within 0.9 mi of the beginning of the taper.

Similar data summaries were prepared for northbound lane closure data, and the results included in Table 3 indicate a pattern similar to the data presented for southbound lane closures. Again, there were factors that complicated evaluations of the differences in traffic control devices. The first 2 days of data collection for northbound traffic involved right-lane closure at the same location. A standard right-lane closure was in operation on the first day, and 21.9 percent of the traffic was in the lane to be closed 0.1 mi in advance of the taper, compared to 10.9 percent in the lane to be closed with a variable message sign added 1.25 mi before the taper. This clearly shows the effectiveness of the variable message sign as a device to promote earlier merging and a smoother flow of traffic through the lane closure. The third traffic control condition of supplemental signs added to the standard left-lane closure and variable message sign was at milepoint 30.1 on I-75 northbound. This was a left-lane closure rather than a right-lane closure, as used for the first and second data collection sites northbound, and the results indicate a much lower



TC 1 - Standard left lane closure traffic control devices
TC 2 - Standard devices with variable message sign
TC 3 - Standard devices, variable message, and supplemental signs
TC 4 - Standard devices, variable message, supplemental signs and rumble strips

FIGURE 2 Distribution of traffic from 3.5 mi in advance to beginning of taper (southbound lane closures).



TC 1 - Standard left lane closure traffic control devices
TC 2 - Standard devices with variable message sign
TC 3 - Standard devices, variable message, and supplemental signs
TC 4 - Standard devices, variable message, supplemental signs and rumble strips

FIGURE 3 Distribution of traffic from 0.9 mi in advance to beginning of taper (southbound lane closures).

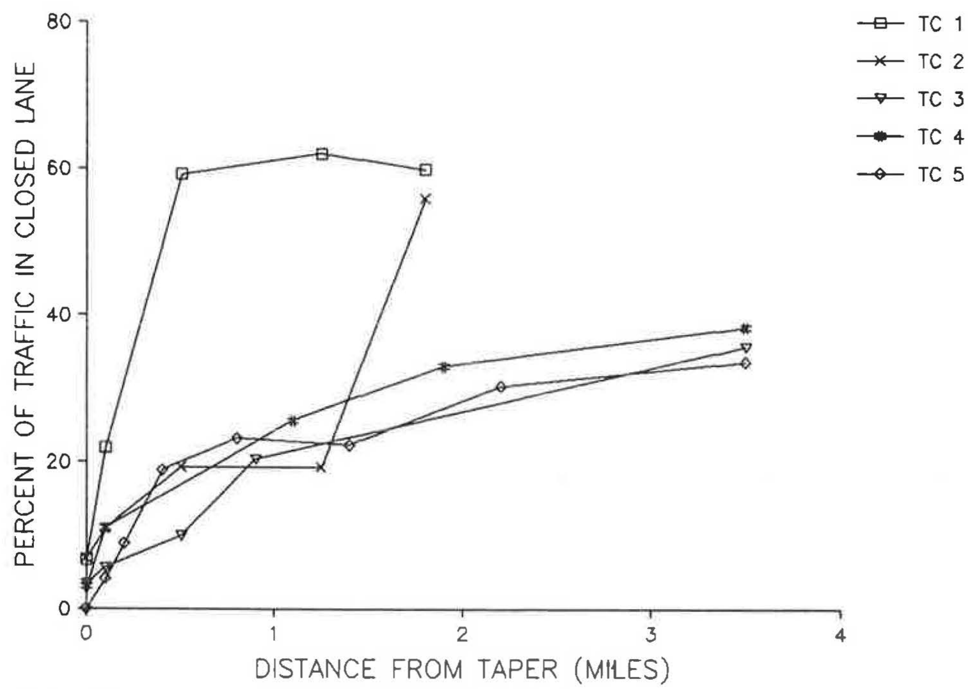
percentage (5.6 percent) of traffic in the lane to be closed 0.1 mi in advance of the taper.

In an effort to determine the impact of rumble strips used in addition to the other traffic control devices, another site was selected at a northbound closure (milepoint 17.9), where data would be collected with all devices except rumble strips and then at that same location with the addition of rumble strips. However, there was an unanticipated change in the construction schedule, and the left-lane closure was not in place for two consecutive weeks. Instead, data were collected at milepoint 17.9 without rumble strips and at milepoint 14.2 with rumble strips added to the other types of traffic control. The results, presented in Table 3, show that the percentage of traffic in the lane to be closed at 0.1 mi in advance of taper decreased from 11.0 percent with all traffic control devices in place except rumble strips to 4.1 percent with rumble strips added at distances in advance of the taper of 1.5, 1.0, 0.6, 0.3, and 0.1 mi. Even with the change in locations for evaluation of rumble strips, there were relatively minor differences in geometrics that may have affected the results. It appears the rumble strips were effective in decreasing the percentage of traffic in the lane to be closed 0.1 mi in advance and at the beginning of the taper. The relationship between percentage of traffic in the lane to be closed and distance from the taper is presented for northbound lane closures in Figure 4. The effects of various traffic control measures within 1 mi of the taper are presented in Figure 5. Data presented in Figure 5 allow a more detailed comparison of percent traffic in the lane to be closed at 1.0 mi, 0.1 mi, and at the taper.

Additional data documenting speeds, percent trucks, and average hourly traffic are presented in Tables 2 and 3. Speed data were collected before the construction zone signs and at a point between the variable message sign and the beginning of the taper. Results indicate a general decrease in speeds as traffic approached the taper; however, speeds still averaged more than 55 mph in the range of 1 mi to 1/2 mi before the taper.

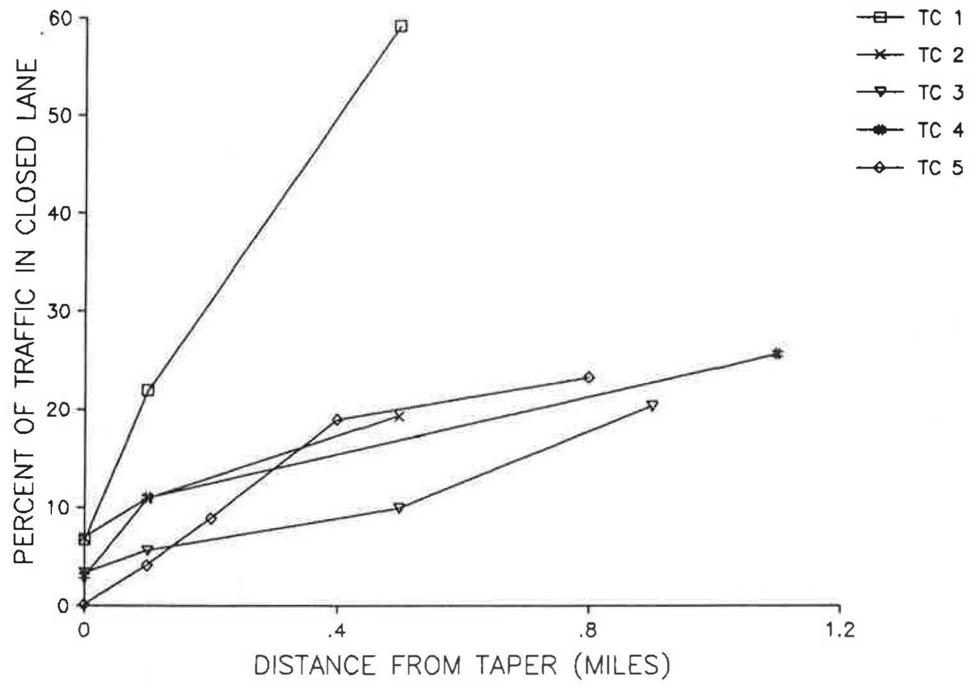
The percentage of trucks was determined for all data collection points, and the results are presented as percentage of trucks in both lanes and the percentage of trucks in the lane to be closed. When the percentage of trucks was averaged for both lanes, it ranged from 8.5 to 14.7 percent. There were generally more trucks on Fridays than on Sundays. Another measure of compliance with the traffic control devices was the percentage of trucks in the lane to be closed. For almost all data collection points, the percentage of trucks in the lane to be closed was lower than the percentage in the open lane when the closure was a left lane. For a right-lane closure, there were more occurrences of a higher percentage of trucks in the lane to be closed than in the open lane. This was obviously affected by the higher percentage of trucks that typically travel in the right lane on four-lane roadways.

Average hourly traffic data, as summarized in Tables 2 and 3, show a range from approximately 800 to 1,300. As stated previously, data were collected on Fridays and Sundays, and the highest volumes were generally on Sundays. For the 6-hr data collection period, the lowest average volumes were on Friday, June 6, and the highest volumes were on Sunday, June 22.



TC 1 - Standard lane closure traffic control devices
TC 2 - Standard devices with variable message sign
TC 3 - Standard devices, variable message, and supplemental signs
TC 4 - Standard devices, variable message, and supplemental signs
TC 5 - Standard devices, variable message, supplemental signs, and rumble strips

FIGURE 4 Distribution of traffic from 3.5 mi in advance to beginning of taper (northbound lane closures).



TC 1 - Standard lane closure traffic control devices
TC 2 - Standard devices with variable message sign
TC 3 - Standard devices, variable message, and supplemental signs
TC 4 - Standard devices, variable message, and supplemental signs
TC 5 - Standard devices, variable message, supplemental signs, and rumble strips

FIGURE 5 Distribution of traffic from 1.1 mi in advance to beginning of taper (northbound lane closures).

Because the average hourly volume was expected to have an impact on the percent of traffic in the lane to be closed, the relationships between these variables 0.1 mi before the taper and at the taper were investigated. The general perception had been that there was a higher percentage of late merges and interrupted traffic flow at the taper with increasing volumes. The data presented in Table 4 indicate relatively little change in volume for the southbound lane closures; it was therefore assumed that decreasing percentages of traffic in the lane to be closed were related to the effectiveness of traffic control devices. For northbound lane closures, the volumes were generally higher but did not appear to influence the percentage of traffic in the lane to be closed.

The interrelationship between percent trucks, hourly traffic volumes, and percent traffic in the lane to be closed was also analyzed (Table 4). It does not appear that a higher percentage of trucks resulted in a higher percentage of traffic in the lane to be closed. For example, at northbound lane closures on July 27 and August 8, there was a decrease in the percent traffic in the lane to be closed (11.0 to 4.1 percent) even though the percent trucks increased from 8.7 to 10.9 percent. It should be noted that average hourly traffic volumes decreased from 1,070 to 950, which also may have contributed to the reduced traffic in the closed lane. In addition, there does not appear to be a relationship between percent trucks in both lanes and the percent trucks in the lane to be closed.

TABLE 4 RELATIONSHIPS BETWEEN HOURLY VOLUMES, PERCENT TRUCKS, AND PERCENT TRAFFIC IN LANE TO BE CLOSED

		Percent Traffic in Lane To Be Closed		Percent Trucks in Lane To Be Closed			
Date	Location	0.1 mi Before Taper	At Taper	0.1 mi Before Taper	At Taper	Percent Trucks (both lanes)	Average Hourly Traffic
6/06/86	I-75 SB, MP 42.2	14.9	3.7	9.6	9.2	11.3	967
6/13/86	I-75 SB, MP 42.2	11.6	3.2	17.3	9.0	11.9	1,068
6/20/86	I-75 SB, MP 42.2	10.4	3.0	5.3	1.5	9.6	1,096
7/11/86	I-75 SB, MP 46.4	7.8	2.1	3.6	3.0	9.2	1,063
6/08/86	I-75 NB, MP 27.2	21.9	6.7	9.1	5.9	11.3	1,047
6/15/86	I-75 NB, MP 27.2	10.9	6.9	13.1	12.4	8.9	1,117
6/22/86	I-75 NB, MP 30.1	5.6	3.3	12.9	11.6	8.5	1,273
7/27/86	I-75 NB, MP 17.9	11.0	3.0	4.3	6.3	8.7	1,070
8/08/86	I-75 NB, MP 14.2	4.1	0.8	9.0	6.4	10.9	950

NOTE: NB = northbound, SB = southbound, MP = milepoint.

SUMMARY

As mentioned previously, guidelines for standard applications of lane closures are detailed in the *Manual on Uniform Traffic Control Devices* (*4*). However, at work zones on some high-volume, high-speed Interstate-type facilities, there may be a need for traffic control devices in addition to those specified as standard applications. For the I-75 pavement restoration project in southern Kentucky during summer 1986, a decision was made by Department of Highways personnel to use the following traffic control devices to supplement standard lane closure devices: variable message sign placed 1 to 2 mi before the taper; supplemental lane closure warning signs 5, 4, 3, and 2 mi before the taper; and rumble strips 1.5, 1.0, 0.6, 0.3, and 0.1 mi before the taper. A summary of primary findings from the evaluation of traffic control devices used in addition to standard lane closure devices follows.

- For all southbound and northbound sites evaluated, there was a decrease in the percentage of traffic in the lane to be closed with the addition of traffic control devices beyond the requirements for devices at standard lane closures.
- There was a decrease in the percentage of traffic in the lane to be closed for southbound sites with each successive traffic control device in addition to the standard devices. The order in which devices were added to the standard lane closure devices was as follows: variable message sign, supplemental lane closure warning signs, and rumble strips placed before the taper.
- Geometric constraints reduced the reliability of data collected at the southbound site when rumble strips were installed in addition to standard lane closure devices, variable message sign, and supplemental signs.
- For one northbound site, the effectiveness of adding the variable message sign to the standard lane closure devices was clearly shown, with a decrease from 21.9 percent to 10.9 percent of the traffic in the lane to be closed 0.1 mi before the taper.
- The effectiveness of rumble strips was demonstrated at the northbound sites when the percentage of traffic in the lane to be closed 0.1 mi before the taper decreased from 11.0 percent with all devices except rumble strips in place to 4.1 percent with rumble strips added.
- Results indicate a general decrease in speeds as traffic approached the taper. However, speed still averaged slightly more than 55 mph in the range 1 mi to 1/2 mi before the taper.
- For almost all data collection points, the percentage of trucks in the lane to be closed was lower than the percentage in the open lane when the closure was a left lane. Overall, the average percentages of trucks for both lanes of traffic ranged from 8.5 to 14.7 percent.
- Average hourly traffic for all sites ranged from 800 to 1,300. Hourly traffic volumes in the range observed in this evaluation did not appear to influence the percentage of traffic in the lane to be closed.
- The percentage of trucks in both lanes did not influence the percentage of traffic in the lane to be closed.
- There does not appear to be a relationship between percentage of trucks in both lanes and percentage of trucks in the lane to be closed.

RECOMMENDATIONS

In general, results of this evaluation indicate that variable message signs, supplemental signs, and rumble strips are effective devices for reducing late merges and provide smoother flow of traffic through lane closures. However, application of these devices in addition to standard lane closure devices should be reserved for special locations where volumes are high and geometric constraints suggest a higher probability for late merges or erratic maneuvers at the closure. Supplemental signs indicating a lane closure 5, 4, 3, and 2 miles ahead should be considered for all long-term closures on high-speed, high-volume four-lane roadways. Variable message signs should be considered at long-term lane closures (in addition to supplemental signs) when one-directional hourly volumes exceed 1,000 (or AADT exceeds 20,000). Application of rumble strips should be reserved for locations where supplemental signs and variable message signs do not reduce late merges and there is excessive congestion due to late merges or other erratic maneuvers at the lane closure.

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