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Speed Control Through Work Zones:

Techniques Evaluation and Implementation Guidelines

Research, Development, and Technology
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McLean, Virginia 22101-2296

FOREWORD

Traffic accidents in highway work zones are a continuing problem. Unsafe operating speed for existing conditions is a frequently cited driver's error which contributes to work zone accidents involving highway traffic. There is a need for more effective methods for controlling vehicle operating speeds through highway work zones.

The information presented in this guide is of interest to traffic engineers in the public and private sectors who are involved in or responsible for planning, designing, and implementing traffic control in highway construction zones on multilane freeways. The guide presents evaluations of four methods for controlling vehicle speeds through work zones on multilane highways where one or more lanes are closed.

The basis for this guide was a field study of vehicle operating speeds through work zones on segments of Interstate highways in Delaware. Copies of the guide are available from the National Technical Information Service, Springfield, Virginia 22161.

Robert J. Betsold
Director, Office of Implementation
Federal Highway Administration

NOTICE

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16. Abstract

This report presents the implementation and evaluation of four techniques for improving the effectiveness of speed zoning in construction areas on multi-lane freeways. The techniques are (a) the flagging procedure of the Manual On Uniform Traffic Control Devices (MUTCD), (b) the use of the MUTCD flagging procedure as well as motioning motorists to slow and pointing at a nearby speed limit sign with the free hand of the flagger, (c) a marked police car with cruiser lights and radar active, and (d) a uniformed police officer standing to control traffic. Each of the techniques were applied continuously on six-lane freeways for a period of 10-15 days. The results of the analysis indicate that all four techniques can derive significant reduction in traffic speed through highway construction zones. The flagging methods were effective in construction areas where one lane remained open to traffic. The law enforcement methods demonstrated a stronger speed reduction capability, particularly when the lane closures result in two or more lanes open. The construction projects used for the field data collection required speed reduction from the regulatory 55 m.p.h. to an advisory 45 m.p.h. although the law enforcement techniques were determined to be effective, their implementation requires a high degree of administrative coordination and cooperation involving police departments, highway officials and construction contractors. A User Guide on speed control in work zones is provided in Appendix B.

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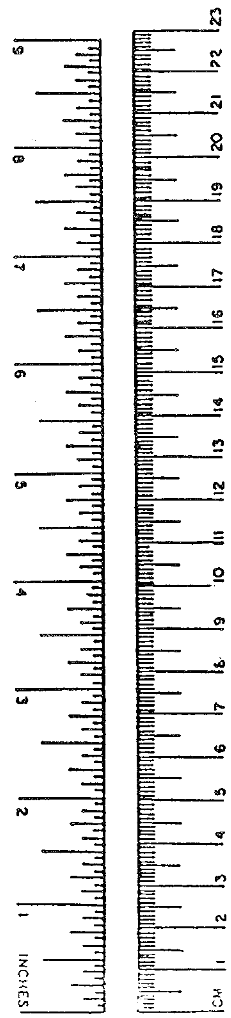
METRIC CONVERSION FACTORS

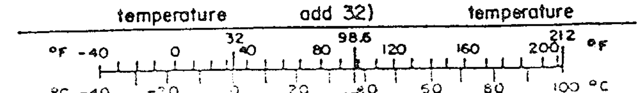
APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

Excessive speed for existing conditions reduces the effectiveness of corrective navigational maneuvers made by motorists as they travel through highway construction zones. The safety of motorists and work crews in construction zones remains an unresolved issue, inspite of numerous techniques for speed control. Traffic accidents in construction sites are a continuing problem. Several studies have concluded that highway construction zones have a propensity for increasing accidents. In a 1965 California accident study (14) of 10 randomly selected construction projects a 21.4% increase in the accident rate was observed, with a 132% increase in the fatality component. In a study of 207 highway resurfacing projects on two-lane highways Graham et al (2) reported a 61% increase in total accidents, 67% increase in injuries, and a 68% increase in fatalities during construction. The Virginia Highway Research Council (15) reported a 119% increase in accident frequency in construction zones on I-495 in Northern Virginia. The National Safety Council surveys (16) show that over 500 people working on the roadway are reported killed each year as a result of traffic accidents. There is no doubt that highway construction and maintenance zones increase the potential for traffic accidents. Attention must be focused on innovative traffic control measures which are more responsive to drivers in highway construction zones. Unfortunately, motorists do not always slow down to posted work zone speed limits.

OBJECTIVE AND SCOPE

This research examines the long-term effectiveness to two flagging and two law enforcement techniques in reducing speeds in freeway construction zones. These techniques were previously determined to have reasonable promise for reducing speeds during 1-2 hour applications (8). The four treatments are the following:

1. MUTCD Flagging: This is the flagging procedure described in the 1978 edition of the Manual On-Uniform Traffic Control Devices (MUTCD) (12). The flagger equipped with a red flag and orange vest performs the "alert and slow" signal detailed in Part IV of the MUTCD.

2. Innovative Flagging: This flagging technique combines the MUTCD procedure with the flagger using the other hand without the flag to motion traffic to slow and then to point at a nearby speed limit sign. See Figure 1.

3. Stationary Police Cruiser with Lights and Radar On: This technique requires a marked patrol car with cruiser lights and radar in operation. See Figure 2.

4. Uniformed Police Traffic Controller: A uniformed officer standing on the side of the road near a speed limit sign manually motions the traffic to slow down. See Figure 3.

Two applications of each of the above techniques were studied on a six-lane Interstate freeway in Delaware. Details of the field sites are presented in the section of this paper which covers the study design.

BACKGROUND

The safety of motorists and workers in highway construction zones has been the subject of many research studies (1, 6, 7, 9, 10, 11,). The results of these studies, as well as others, have contributed to major improvements in the way traffic is controlled to improve safety in highway construction zones. The 1978 version of the Manual on Uniform Traffic Control Devices (12) and its periodical revisions represent the results of years of experimentation, and is the national engineering standard for highway traffic control, including traffic control in maintenance and construction zones. Inspite of great progress in reducing the accident rates in construction zones, safety remains a continuing issue, primarily because of the tragic nature of accidents in construction zones. The fundamental hypothesis of this research is that further reduction in the rate, frequency and severity of accidents in construction zones could be obtained through the use of improved techniques for causing drivers to reduce speeds.

The causes of traffic accidents in highway work zones are due to a combination of factors, including driver's error, inadequate visibility, poor road surface condition, construction obstructions, inadequate traffic control and information, and improper management of material, equipment and personnel in construction zones. Liberty Mutual Insurance Company (3) noted that more than one-half of the accidents in the vicinity of road closures are caused by driver's error and negligence. Unsafe operating speeds for existing condition is a frequent driver's error. In the review of work zone accidents on rural highways in Ohio, Nemeth (5) concluded that compared to other causative factors, excessive speed is 5.5 times more frequently cited as the reason for traffic accidents in highway construction areas. Humphries (4) studied 103 work zones located in several states and concluded that both unsafe operating speed and inadequate speed control can be blamed for many traffic accidents in highway construction zones. Richards and Faulkner (13) studied accidents in Texas and observed that speed violation contriubted to 27 percent of work zone accidents, compared to 15 percent for non-work zone accidents. There is need for more effective ways for motorists to reduce speed in highway construction zones where slower operating speeds are required. The standard practice of using signing to control speeding in work zones is not working. Drivers are generally not responsive to purely advisory and regulatory speed signing in construction zones.

Figure 1. Innovative Flagging Method

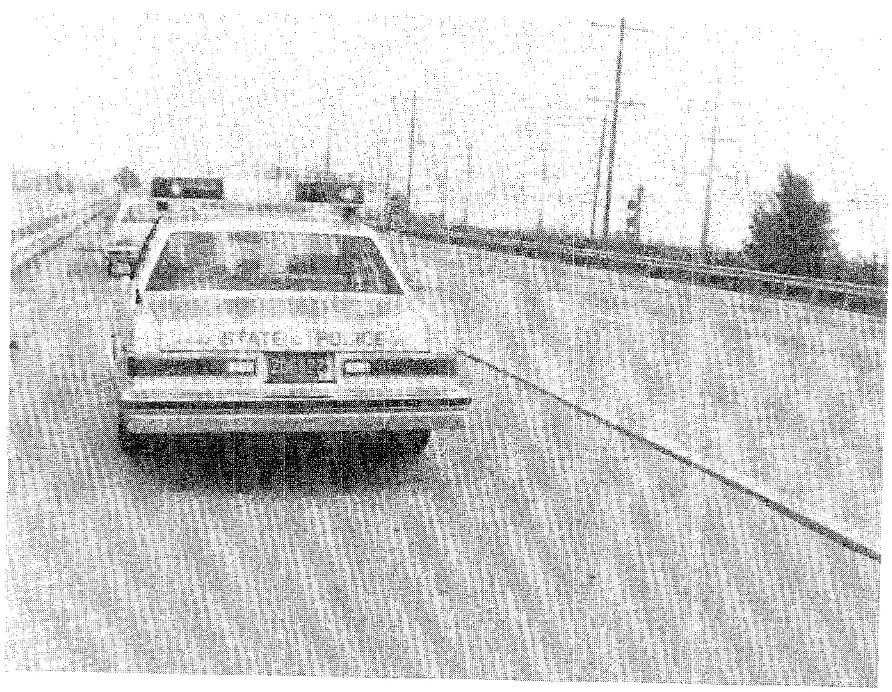


Figure 2. Police Cruiser With Lights and Radar

Figure 3. Uniformed Police Traffic Controller

Graham et al (2) conducted experiments to evaluate several speed reduction techniques for highway work zones in the Kansas City Metropolitan area. The study observed speed, erratic maneuvers and conflicts at three sites -- an urban freeway, rural freeway, and an urban street --. Data collection was limited to 2 - 3.5 hours per technique. The study did not address the long term speed reduction potential of each technique.

Richards et al (8) studied the short term effectiveness of a number of work-zone speed reduction methods. The flagging technique described in the MUTCD (12), an innovative flagging modification of the MUTCD method, police controller, and police car with activated radar on site were among the techniques studied. The study (8) examined the short-term speed-reduction response of motorists to each technique. Observations for each treatment were made over 1 - 2 hours. Compared with the standard MUTCD flagging method, the innovative flagging treatment resulted in larger speed reduction at five of the six study sites. On the urban freeway site, the innovative flagging treatment reduced speeds by 4 mph (7%) and the MUTCD flagging reduced speed by 3 mph (5%). These reductions, from a traffic operational standpoint are not significant. The report (8) states that the police controller technique was not evaluated at any of the freeway sites because of the reluctance of the police to stand on the roadside. The stationary patrol car reduced speeds by 4 - 12 mph (6 to 22%). It was determined to be the most successful on urban arterials and apparently less so on urban freeways. These four speed reduction techniques were determined to have modest promise, based on short term observations of 1 - 2 hour durations. The unanswered question is whether the potential demonstrated for the short term application of the four techniques can be obtained during long term application on freeways. Construction activities of duration longer than two weeks are common occurrences on freeways. Thus, the experiments initiated by Richards et al (8) need to be expanded to cover long term conditions.

IMPLEMENTATION

Study Sites

Eight study sites were selected on Route I-495 in the suburbs of Wilmington, Delaware. I-495 is a six-lane divided freeway, with three lanes in each direction. Figure 4 shows the relative location of the four bridges which were undergoing approach slab rehabilitation during the study. For each bridge, the construction activity was performed in two phases. The left and center lanes were closed in phase 1, and the right lane was closed in phase 2. Figure 5 demonstrates the typical two-lane closure used on all sites. The typical one-lane closure is depicted in Figure 6. Figures 5 and 6 also provide information on the location of treatment stations in relation to the sensors at speed stations A, B, and C. Station A was placed about 5000 feet upstream away from Station B. The regulatory speed limit at Station A was 55 mph. An advisory speed of 45 mph was installed throughout the construction area. All study sites had the same geometrical, topographical, and traffic operating conditions. The distance between B and C was either 2500 or 4500 feet depending on the number of lanes closed. Table 1 provides a listing of the treatments and the spacial separation between speed stations. Traffic control devices in the construction area were not visible from Station A. Figure 7 indicates the typical off-peak traffic, roadway geometrics, and scenic conditions of the study sites.

Table 1. Lane Closures and Distances Between Stations

Treatment Type	Site No.	Freeway **	Unidirectional Lanes	Lanes Closed	Distance Between Stations (ft)	
					A-B	B-C
MUTCD	802	I-495S	3	CL & LL	5000	4500
MUTCD	802	I-495S	3	RL	5000	2500
Police Car & Radar	805	I-495N	3	CL & LL	5000	4500
Police Car & Radar	805	I-495N	3	RL	5000	2500
Police Controller	813	I-495N	3	CL & LL	5000	4500
Police Controller	813	I-495N	3	RL	5000	2500
Innovative Flagging	826A	I-495N	3	CL & LL	5000	4500
Innovative Flagging	826A	I-495N	3	RL	5000	2500

CL = Center Lane
RL = Right Lane
LL = Left Lane
MUTCD = Flagging procedure in the <u>Manual of Uniform Traffic Control Devices</u>

** All sites located in Wilmington, Delaware

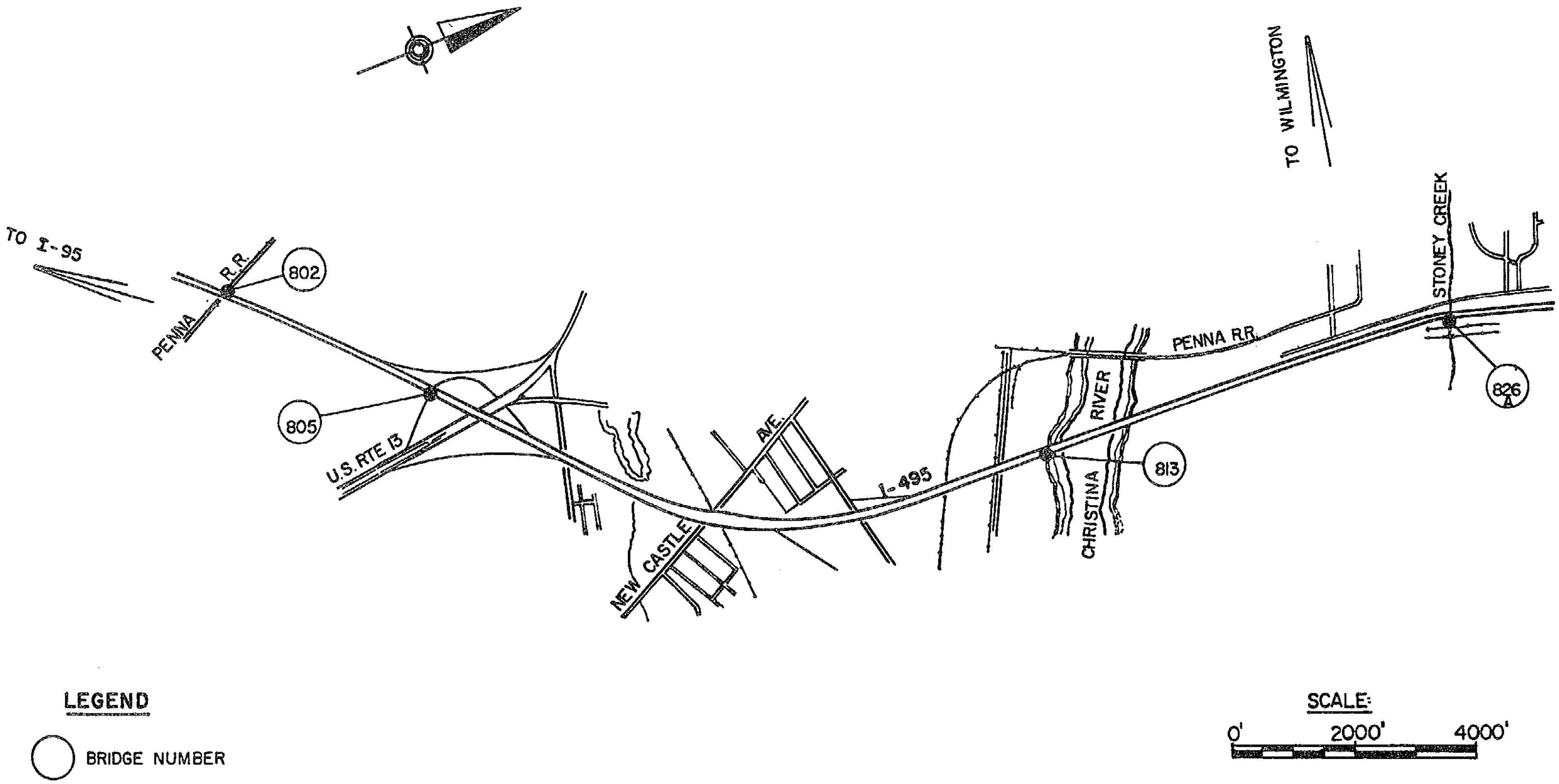
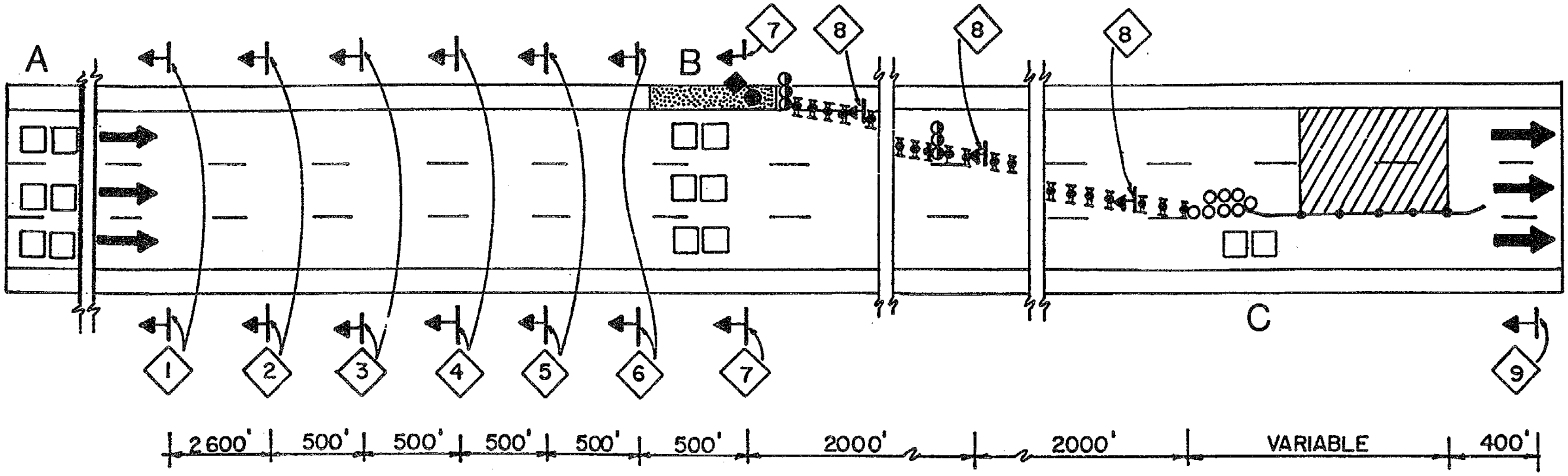


Figure 4. Location Map of Field Sites in Suburban Wilmington, Delaware



LEGEND

1	ROAD CONSTRUCTION ONE MILE, WITH ADVISORY 45 MPH SPEED PLATE	9	END CONSTRUCTION
2	LEFT LANE CLOSED HALF MILE, WITH ADVISORY 45 MPH SPEED PLATE		ARROW BOARD
3	MERGE RIGHT		FLAGMAN
4	LEFT LANE CLOSED 1500 FT.		DIRECTION OF SIGN
5	MERGE RIGHT		SPEED MAT (SENSOR)
6	FLAGMAN AHEAD, WITH ADVISORY 45 MPH SPEED PLATE		TREATMENT STATION
7	ADVISORY 45 MPH SPEED SIGN FOR FLAGGING TREATMENT ONLY		WORK AREA
8	KEEP RIGHT	A, B and C	SPEED STATIONS

Figure 5. Schematic of Typical Left and Center Lane Closure

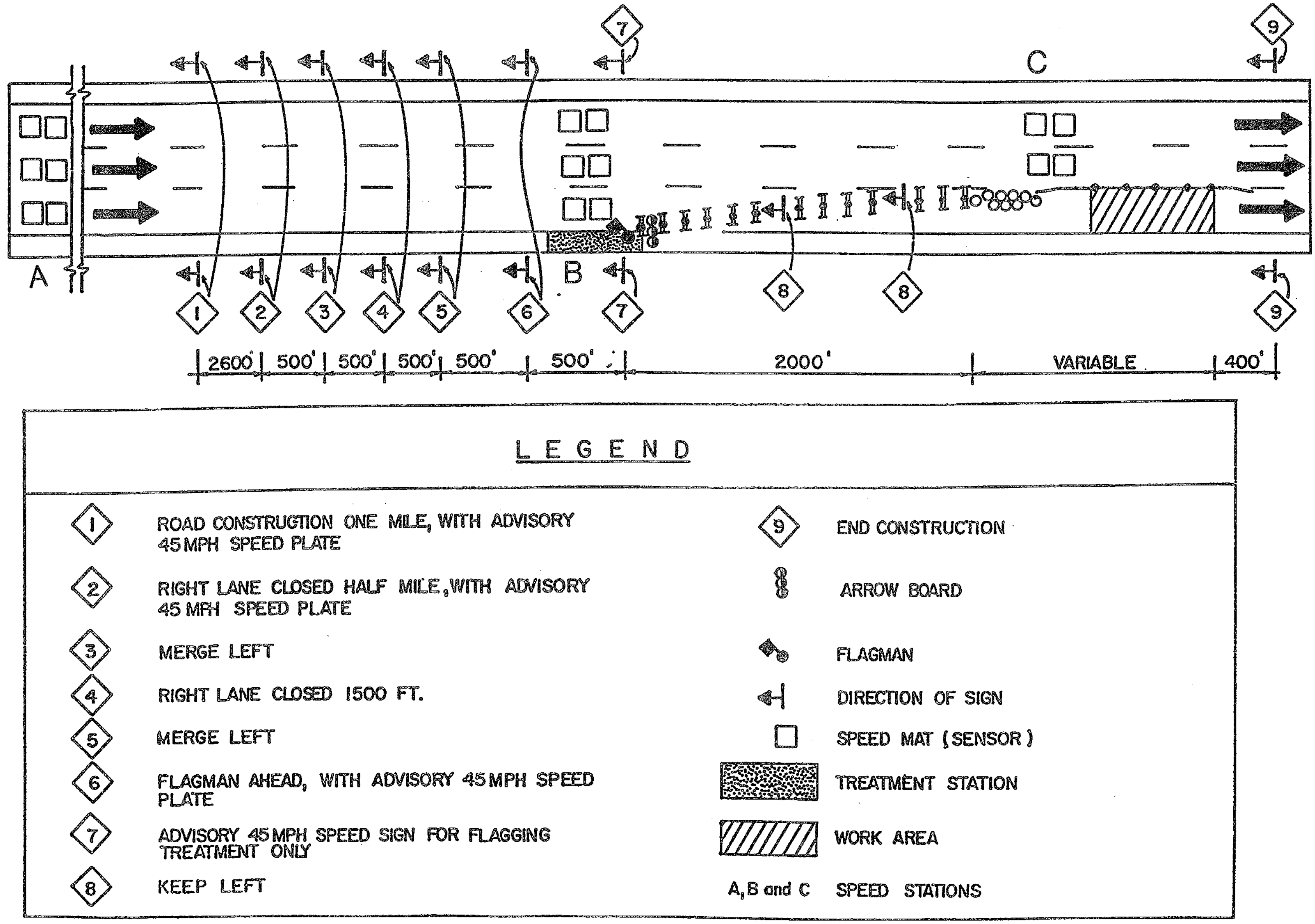


Figure 6. Schematic of Typical Right Lane Closure

Application of Treatments

Each of the four treatments was applied once to the two-lane closure phase and then to the one-lane closure phase for the same bridge. No treatment was repeated on any other bridges. For example, the MUTCD flagging was applied only to bridge #802 during phase 1 and phase 2 construction for that bridge. See Table 1 for treatments and lane closures applied to other bridges. The treatment applied to each lane-closure situation remained in place for a period of 10 - 15 days, depending on the schedule of the construction contractor.

Environmental Conditions

The observation periods, occurred on weekdays only and lasted approximately for three hours, involved good weather, and dry pavement, and were carefully selected to avoid night conditions and peak traffic periods.

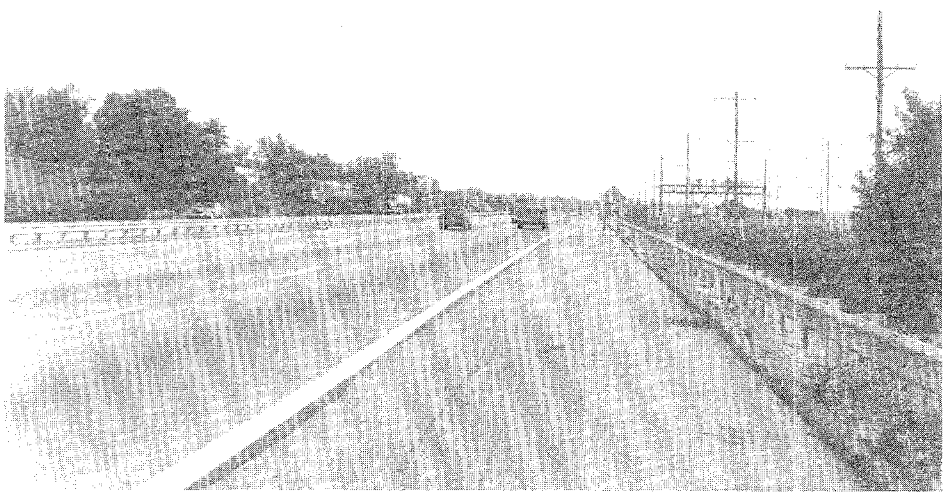


Figure 7. Typical Roadway Characteristics

Instrumentation

Automatic data collection equipment was used in obtaining speed, volume and vehicle classification. Two portable electromagnetic loop detectors mounted on rubber mats (see Figure 8) were used in each through lane. These mats were nailed to the pavement as indicated in Figure 9. A special adhesive duct tape was used to further secure the edges of the mats and the lead wires. One VC 1900 traffic analyser (see Figure 10) was used at each speed station. Figure 11 demonstrates a completely installed mat. Figure 12 depicts the layout used in covering three lanes opened to traffic. Lead wires from each detector were connected to the traffic analyser. Use of the above mentioned equipment facilitated concealment and avoided the need for the field team to remain on site while data were being automatically collected.

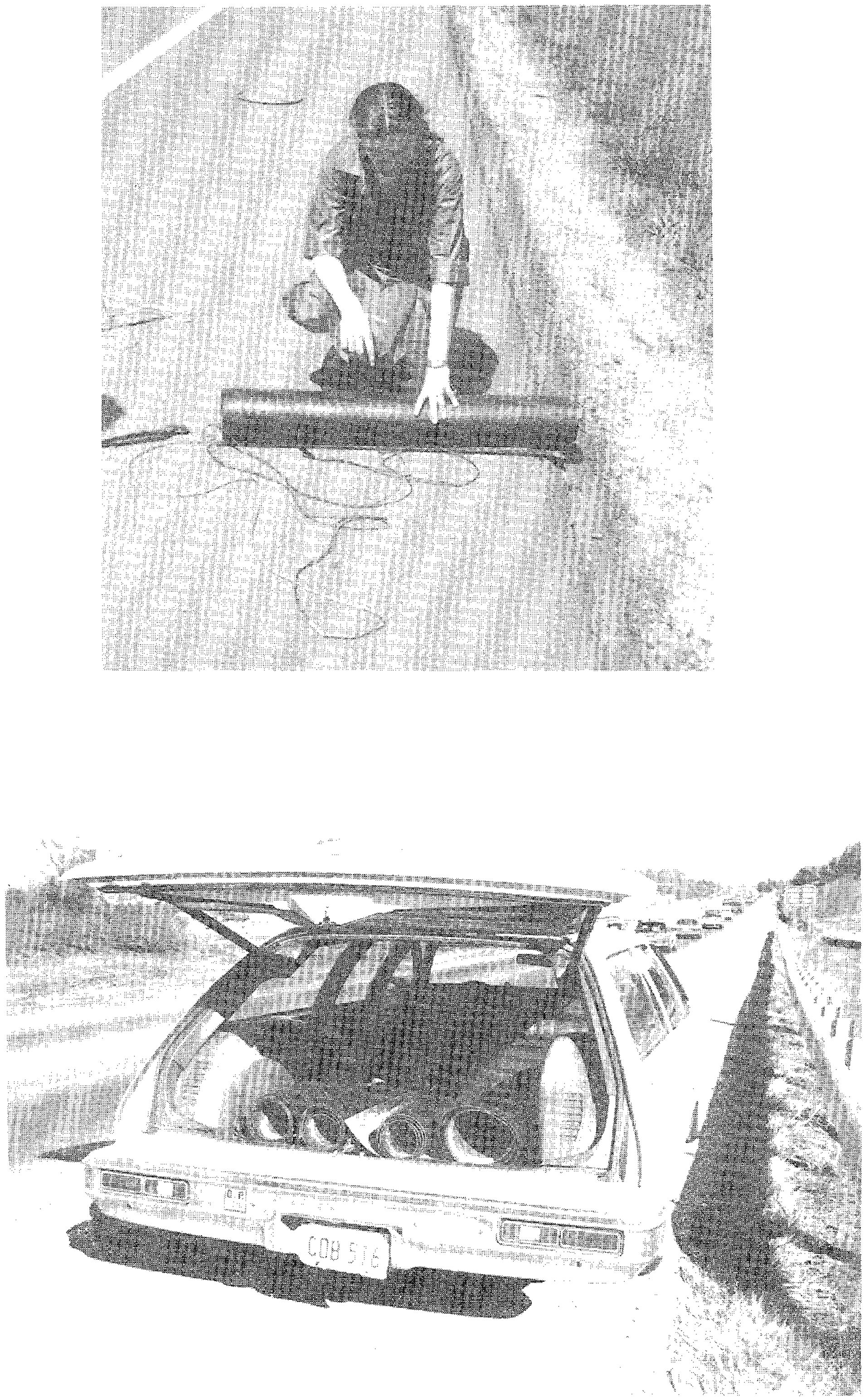


Figure 8. Portable Electromagnetic Loop Detectors

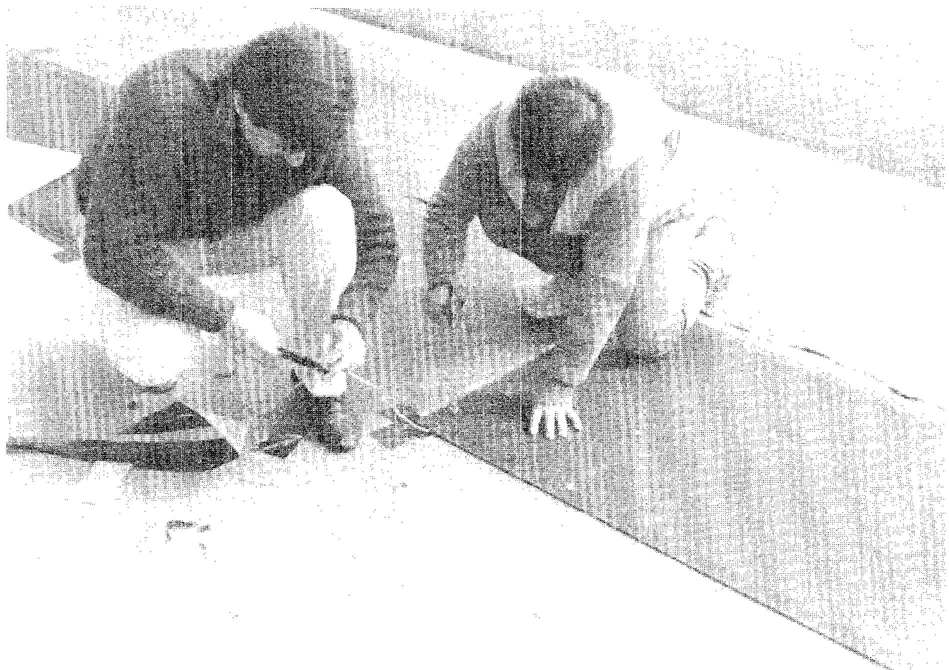


Figure 9. Nailing Mats and Attaching Lead Wires

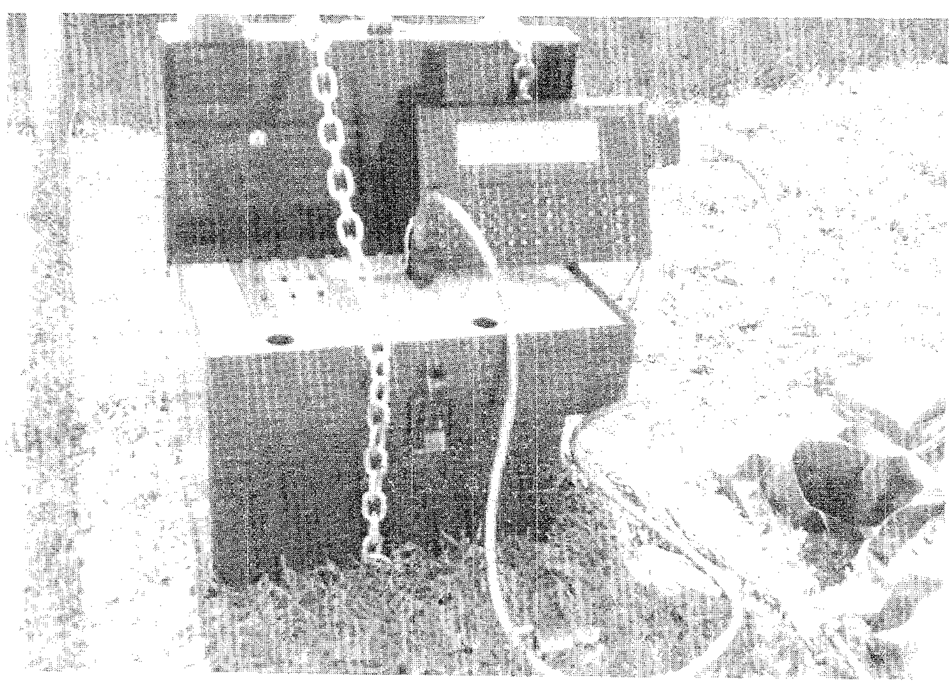


Figure 10. Traffic Analyser and Portable Computer

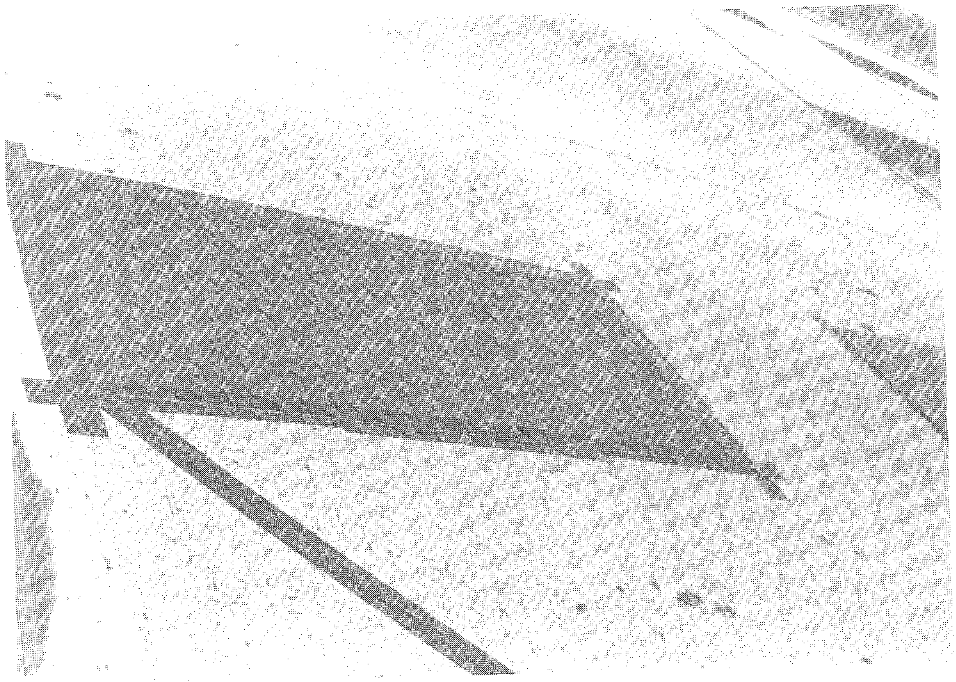


Figure 11. Installed Speed Mat

Figure 12. Typical Layout of Speed Mats on Three Lanes

Data Collection Procedure

For each treatment speed observations were made at the three speed stations (A, B, and C) prior to implementation, within the first three days of implementation, and about 10 - 15 days after implementation. The 10 - 15 day exposure period depended on construction progress. No treatment received less than a ten-day exposure. Observation at all three stations were planned to be simultaneous, inspite of the separation between speed stations. However, random damage to the speed sensors attached to the pavement did not allow for exactly simultaneous measurements at all three stations. For each treatment and speed station, at least 100 speed observations per lane were made, except for speed stations preceding the tapered one and/or two-lane closure. Occasionally, the fast lanes were less frequently used than the other two lanes and thus resulted in less than 100 speed observations for same time periods. All the lanes which were opened to traffic at the three speed stations were equipped with sensors to detect speed and classify vehicles in two categories (cars and trucks.) The VC 1900 traffic analyser was programmed to detect the speed and type of vehicles separated by a selected headway of 4 seconds. The Husky Hunter portable microcomputer was used to program the traffic analysers placed at each speed station. Vehicle data were electronically stored in the memory of the traffic analyser and were retrieved periodically using the Kaypro 2000 portable microcomputer which is compatible with the IBM personal computer. Once the equipment at all speed stations were programmed for data collection, the field team left the stations and took on a supervisory role, with periodical observation of the equipment.

Data Reduction

The means and standard deviations of speed for each treatment are presented in Table 2. Figures 13 and 14 represent the speed profile for one-lane and two-lane closures for all vehicles. Similar profiles for cars and trucks are presented in Figures 15 and 16 and Figures 17 and 18, respectively. Although the long term speed reduction capability of some treatments are already being hinted in the graph and tabulation of unadjusted data — for example the Police Car and Radar showing a consistent decrease in speed from base to late periods —, consideration must be given the speed changes due to differences in driver population across the periods.

Statistical Method

All statistical analyses were done on an AT&T microcomputer using PC-SAS (Statistical Analysis System for Personal Computers). The experimental design provided statistical controls for site differences and driver populations within sites by incorporating speed data from a base station (Station A) and a base period across all stations. A one-way analysis of variance procedure was used to compare mean driver speeds among the treatments. The driver speeds were adjusted for potential differences in the driving population prior to the analysis by subtracting the mean driver speeds at the base station (Station A). This adjustment assumes that the driver speeds at Station A adequately reflect the speeds of the population of

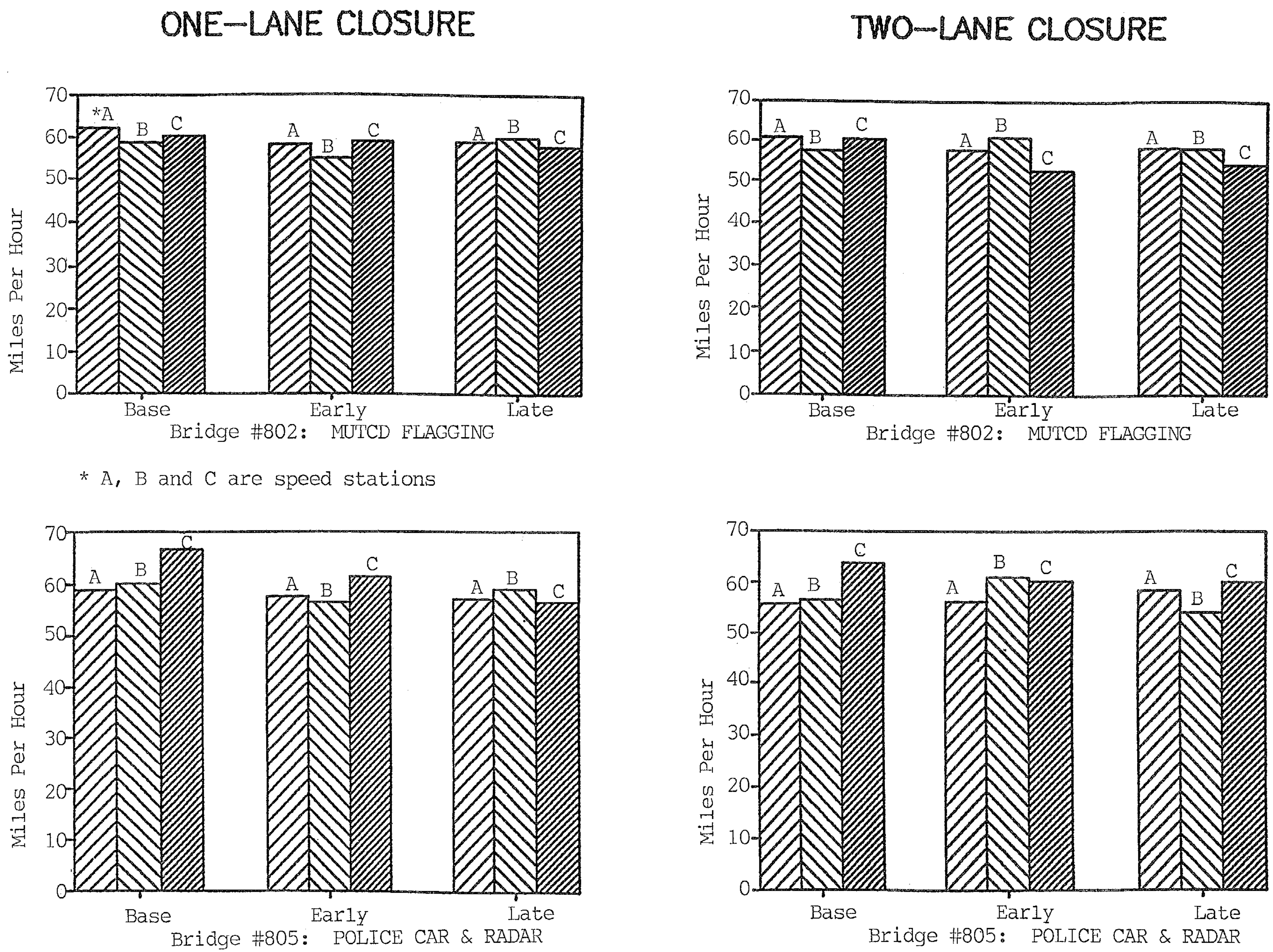


Figure 13. Speed Profiles for All Vehicles on Bridges No. 802 and No. 805

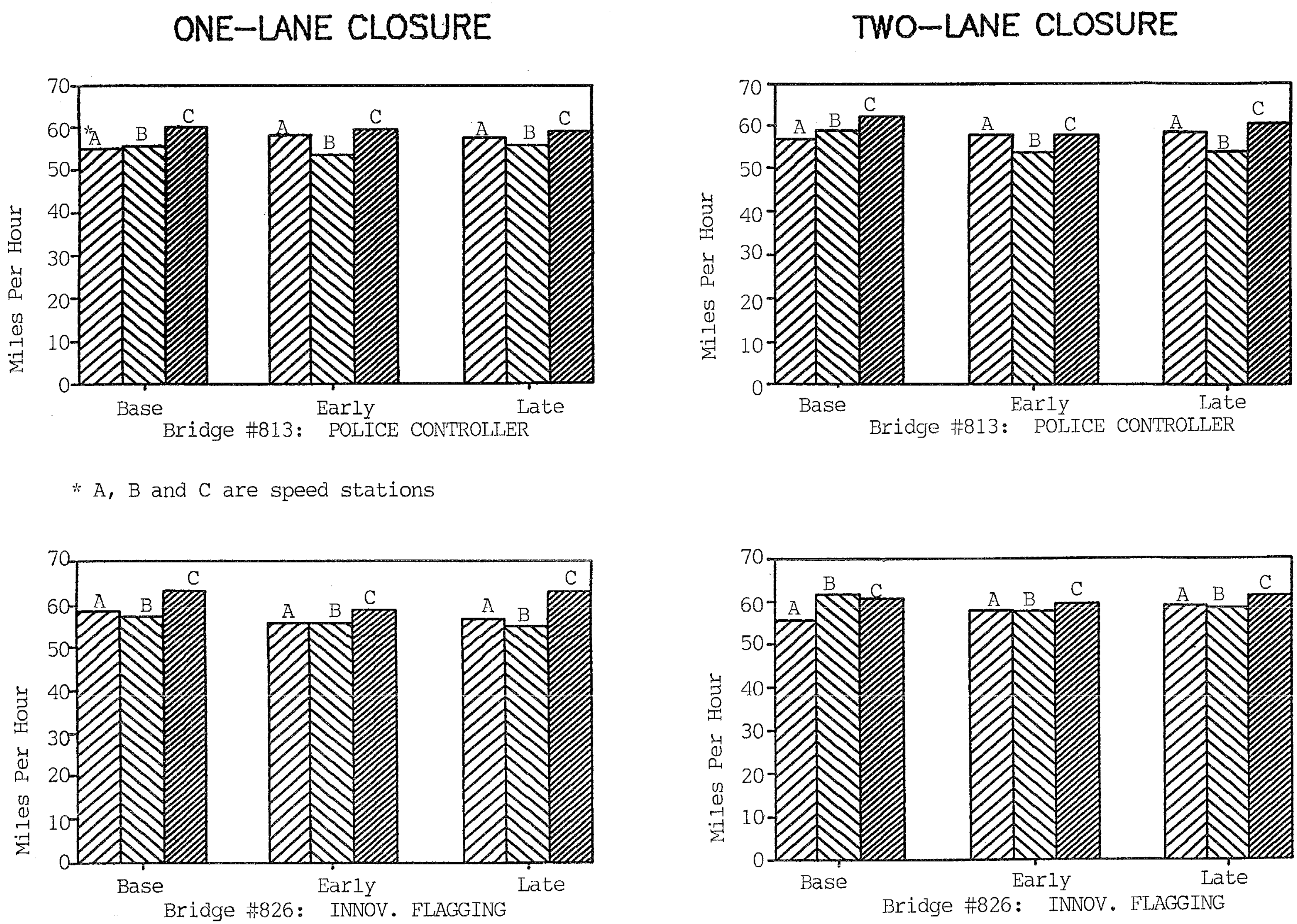


Figure 14. Speed Profiles for All Vehicles on Bridges No. 813 and No. 826

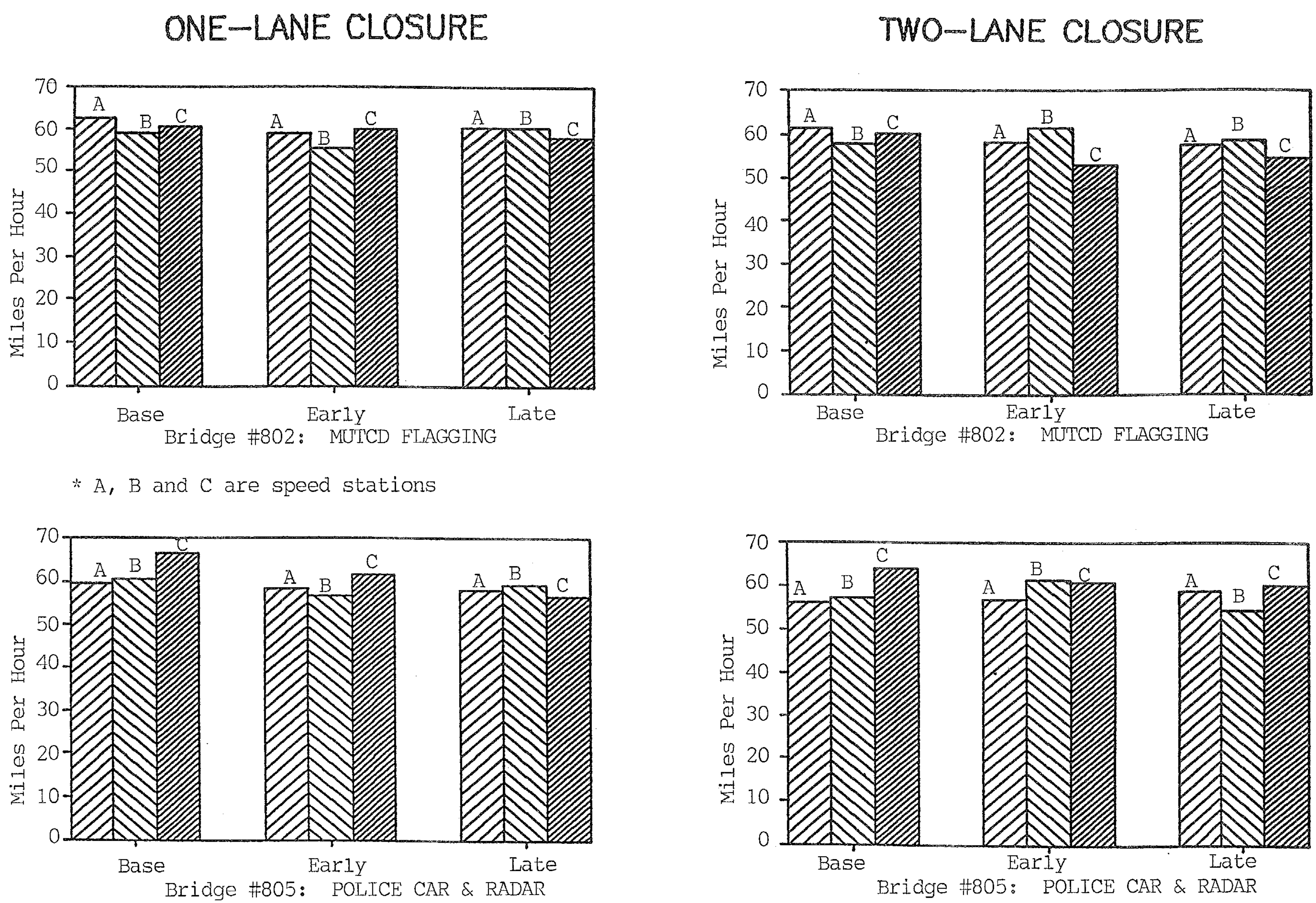


Figure 15. Speed Profiles for Cars on Bridges No. 802 and No. 805

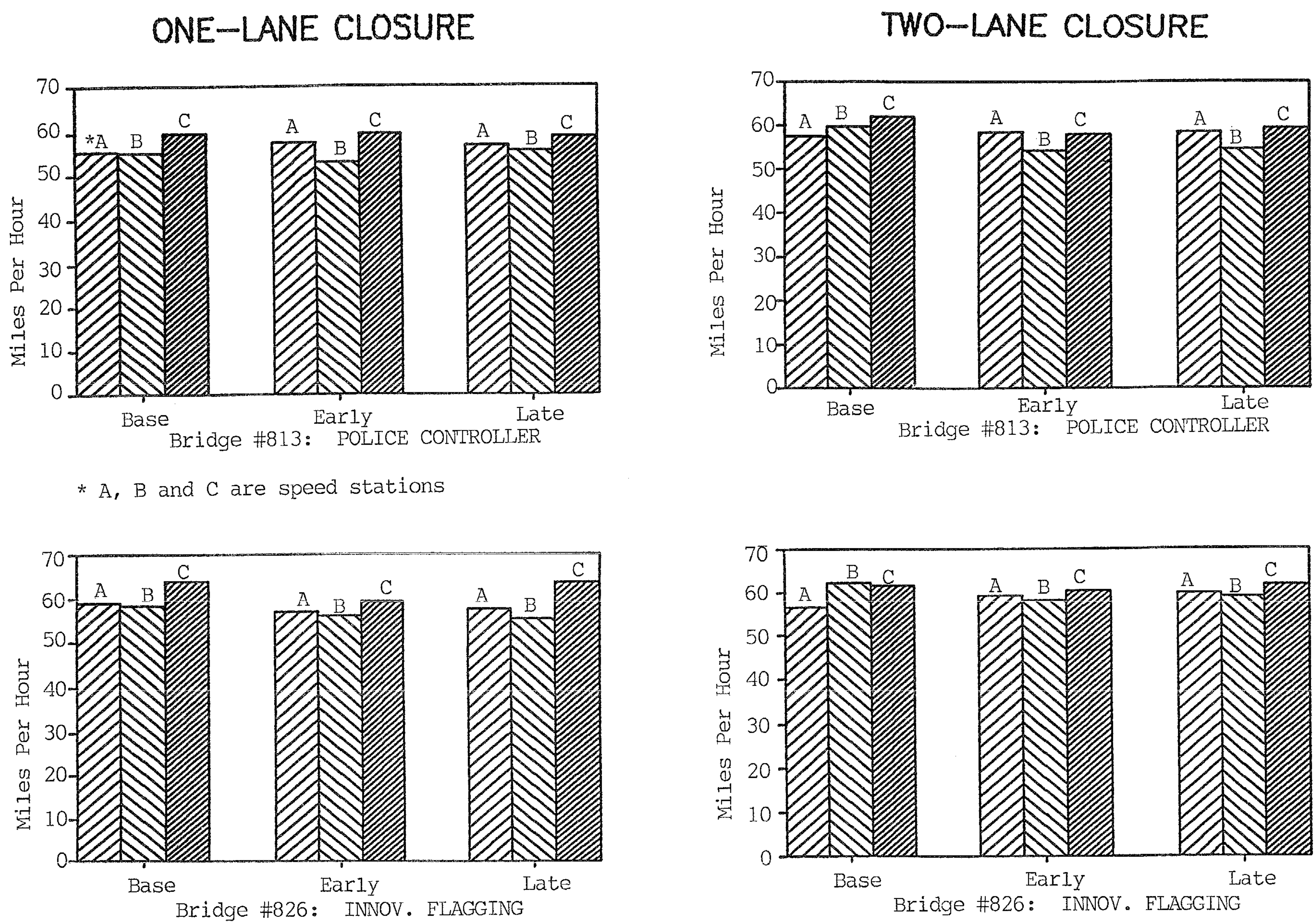


Figure 16. Speed Profiles for Cars on Bridges No. 813 and No. 826

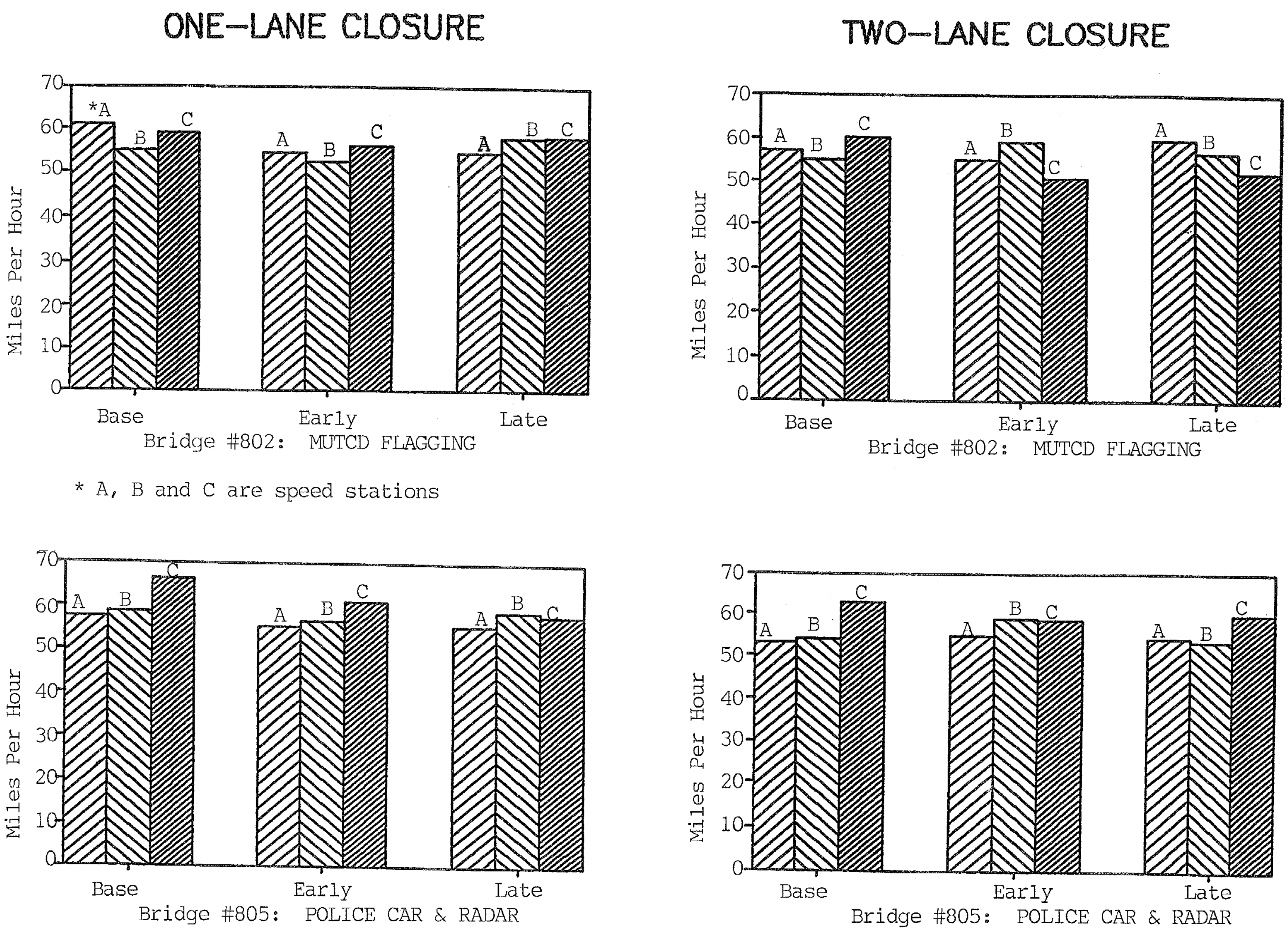


Figure 17. Speed Profile for Trucks on Bridges No. 802 and No. 805

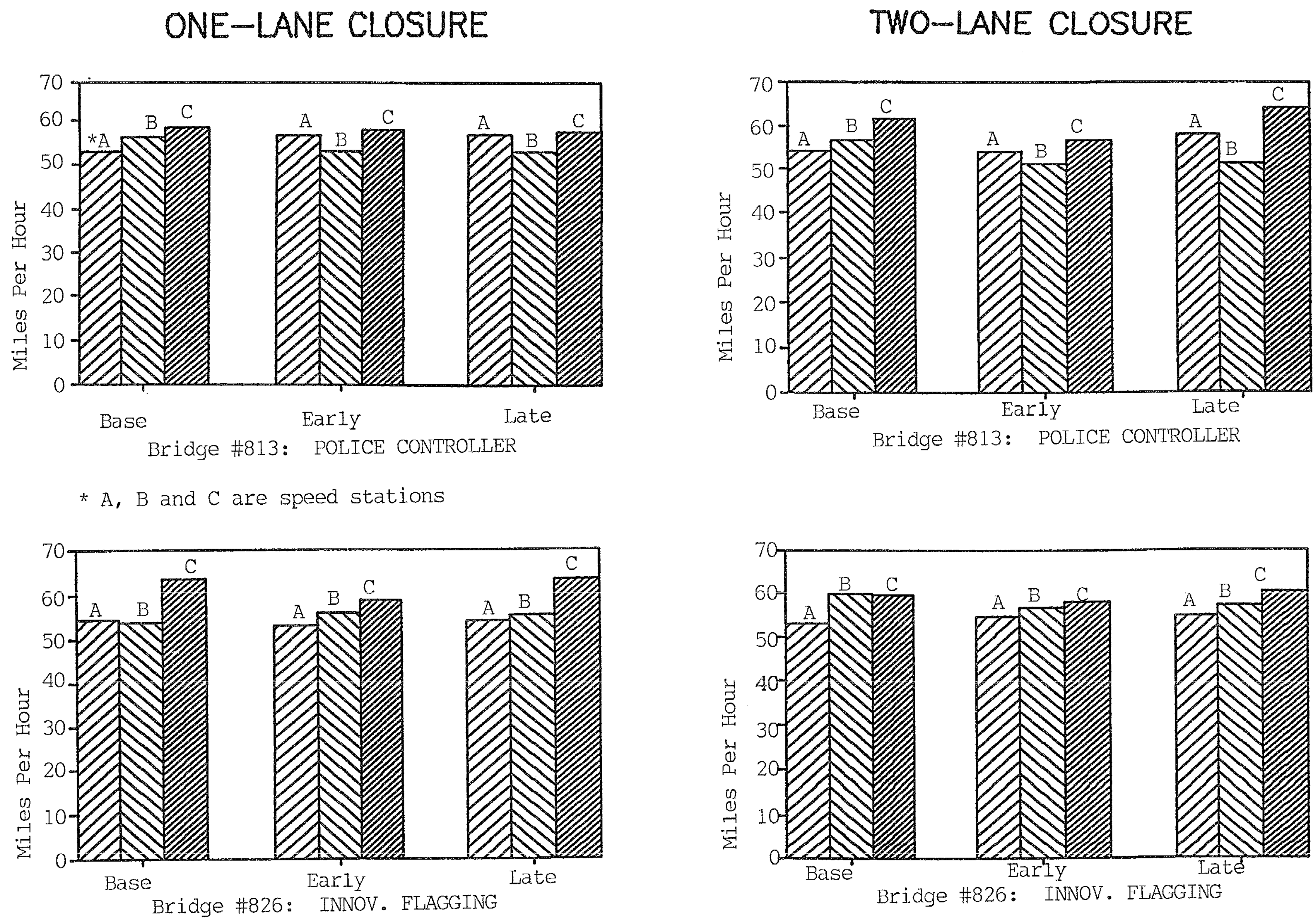


Figure 18. Speed Profile for Trucks on Bridges No. 813 and No. 826

Table 2. Means and Standard Deviation of Speeds of All Vehicles

Treatment	Lanes Closed	STATION A						STATION B						STATION C					
		Base		Early		Late		Base		Early		Late		Base		Early		Late	
		$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
MUTCD Flag	CL & LL	60.8	5.7	57.7	6.5	58.4	8.3	57.3	7.8	60.9	7.2	58.2	7.1	60.4	6.1	52.6	6.6	54.2	7.7
MUTCD Flag	RL	62.2	7.1	58.3	7.8	59.0	8.0	58.8	6.0	55.1	6.0	60.0	5.8	60.5	7.1	59.2	7.1	58.1	4.9
INN. Flag	CL & LL	55.6	6.8	57.9	7.1	59.0	7.9	61.8	7.7	57.7	7.8	58.5	7.1	60.8	7.2	59.5	7.8	61.2	7.0
INN. Flag	RL	58.8	5.7	56.0	5.5	57.2	5.5	57.5	6.5	56.1	6.6	55.6	6.6	63.8	6.3	59.3	6.2	63.6	6.2
Police Car and Radar	CL & LL	55.6	5.4	56.3	6.5	58.3	5.9	56.6	5.6	60.9	7.0	53.9	5.6	63.6	6.2	60.3	7.6	59.9	6.1
Police Car and Radar	RL	59.0	8.2	57.9	6.0	57.6	5.7	60.2	6.6	56.7	5.6	59.3	6.0	66.7	5.5	61.6	5.2	56.9	8.1
Police Controller	CL & LL	56.7	6.8	57.7	6.5	58.4	6.6	58.9	7.0	53.6	6.6	53.8	6.4	62.0	7.6	57.7	7.4	60.4	6.7
Police Controller	RL	54.9	7.0	57.8	7.1	57.2	6.9	55.5	6.9	53.3	6.8	55.5	6.2	59.9	8.0	59.3	7.1	58.9	6.6

*located in active construction area $\overline{X}$ = means speed (mph) S = standard deviation drivers and that this population of drivers has the same variability at all stations. This assumption of equal variability was statistically tested and found to be valid at the .05 level of significance. The mean driver speeds among the stations were ranked and compared using the Scheffe' method of multiple comparison (17). The individual levels of signifance for these multiple comparison tests were adjusted so that the overall conclusions drawn are reliable at the .05 level of significance. Further details of these statistical methods can be found in the Appendix.

EVALUATION OF SPEED CONTROL TREATMENTS

Measure of Effectiveness

This analysis compared the effects of the four speed control treatments (Police Radar, Police Controller, Innovative Flagging, MUTCD Flagging) during the base (reference condition without any treatment) and early (within a few days after implementation of the treatment) time periods and during the base and late (10-15 days of continuous exposure) periods. The early and late periods represent the short term and long term, respectively.

The effect of the treatment was evaluated based on the estimated expected speed change at Station C adjusted for the actual speed change at the upstream base station, Station A. In assessing the effect of the treatments at the point of application, Station B was used in place of Station C. However, the most dramatic treatment effect was anticipated at Station C.

The unadjusted speed change at Station C due to a speed control treatment was estimated by subtracting the average speed at Station C during the early period from the average speed during the base time period. This average speed change at Station C was then adjusted for differences in speeds that might be anticipated under no speed control treatment conditions (i.e., differences due to changes in the driver populations between the base and early periods). The net speed change was estimated by subtracting the average speed at Station A during the base time period. Since traffic at the upstream Station A was not influenced by the speed control treatment implemented near Station B, changes in average speed at Station A, between the base and early periods, could be assumed to be the result of differences in driver populations. Thus, average speed differences at Station C were adjusted accordingly. The same procedure was used in estimating the net speed change at Station B.

Table 3 summarizes the estimated average (net) speed changes at Stations A and C and the expected net average speed changes at Station C after adjusting for Station A speed differences. For example, for the MUTCD Flagging one-lane closure for all vehicles (cars and trucks), the difference in average speed between the base and early period at Station A was -3.9 mph and -1.3 mph at Station C, for a net change at Station C of +2.6 mph ([-1.3] - [-3.9]). Note that for the MUTCD Flagging speed control treatment to be effective, the average speed at Station C should have decreased by more than 3.9 mph. However, there was actually a net increase in speed at Station C.

Table 3. Average Speed Changes (MPH) - Base Vs. Early Periods

	One-Lane Closure			Two-Lane Closure		
	Station A	Station C	Net Change Station C	Station A	Station C	Net Change Station C
All Vehicles						
MUTCD	-3.9	-1.3*	+2.6*	-3.1	-7.8*	-4.7*
Police with Radar	-1.1	-5.1*	-4.0	+0.7	-3.3*	-4.0*
Police Controller	+2.9	-0.6*	-3.5*	+1.0	-4.3*	-5.3*
Innovative Flagging	-2.8	-4.5*	-1.7*	+2.3	-1.3*	-3.6*
Cars						
MUTCD	-3.5	-0.7	+2.8	-2.7	-7.1	-4.4
Police with Radar	-1.3	-5.0	-3.7	+0.5	-3.0	-3.5
Police Controller	+2.3	0.0	-2.3	+0.7	-3.9	-4.6
Innovative Flagging	-2.1	-4.5	-2.4	+2.6	-1.3	-3.9
Trucks						
MUTCD	-6.8	-3.0	+3.8	-2.1	-9.3	-7.2
Police with Radar	-2.0	-5.1	-3.1	+1.7	-4.2	-5.9
Police Controller	+3.8	-0.6	-4.4	-0.1	-4.9	-4.8
Innovative Flagging	-1.4	-4.8	-3.4	+1.4	-1.5	-2.9

The statistical method used to evaluate treatment speeds was the analysis of variance. A two-way analysis of variance model was applied to the base and early data of Station C for all treatments, adjusted for Station A speeds for each respective treatment period. The factors in the analysis of variance were 1) site, 2) treatment period (base or early), and 3) site by treatment interaction. The interaction hypothesis in these two-way analysis of variance tables was equivalent to testing equality among the speed changes in columns labeled "net change" in Table 3. The adjusted (net change) estimates were tested using a modified interaction test.

If there was a significant overall difference in net speed change, the next step was to determine which treatments were different. This was done using the Scheffe's test for multiple comparisons at the overall level of significance of .05 for three contrasts.

The results of these statistical tests are summarized in Table 4. These results were interpreted separately for one- and two- lane closure conditions.

Short-Term Exposure at Station C

One-Lane Closure

Statistically, the Police Radar and Police Controller treatments with net average speed changes of -4.0 and -3.5 mph were equally effective and were significantly more effective in reducing speeds than the Innovative Flagging and the MUTCD Flagging treatments with net average speed changes of -1.7 and +2.6 mph during the field studies. However, since the difference in speed reductions for the Police Radar and the Police Controller was at most 2.3 mph greater ([-4.0] - [-1.7]) than the Innovative Flagging, from a practical standpoint, one cannot say that the Police Radar and Police Controller treatments were better than the Innovative Flagging.

The net average speed increase of 2.6 mph for the MUTCD Flagging was significantly different from any of the other treatment effects. Please note that the site where the MUTCD Flagging was studied was the first site at which data were collected and analyzed.

Analysis of cars only indicated that the Police Radar treatment, with an average speed change of -3.7 mph, was statistically significantly better than the other treatments. The Innovative Flagging treatment was found to be as effective as the Police Controller treatment in reducing average speeds. There was no statistically significant difference in average speed reductions between the Innovative Flagging and Police Controller treatments (-2.4 vs -2.3 mph). From a practical standpoint, there were no differences between the Police Radar, Police Controller and Innovative Flagging treatments.

The net average speed of cars during the MUTCD Flagging treatment increased by 2.8 mph. The results of the analysis of truck only data were similar to that of cars only. The Police Controller, Innovative Flagging and Police Controller resulted in statistically significant reductions in net average truck speeds of 4.4, 3.4 and 3.1 mph. The MUTCD Flagging resulted in a net increase of 3.8 mph in average truck speed.

Two-Lane Closure

For the two-lane closure condition, the net average vehicle speeds for all four speed control treatments were both statistically and practically lower than the speeds during the base conditions. The average speeds were reduced by a net of 5.3, 4.7, 4.0 and 3.6 mph for the Police Controller, MUTCD Flagging, Police Radar and Innovative Flagging treatments. There were no statistically significant differences among the four treatments.

Table 4. Ranking Within One- or Two-Lane Closures
Station C Early Treatment Effect

One-Lane Closure		Two-Lane Closure	
All Vehicles			
1. Police Radar	-4.0	1. Police Controller	-5.3
2. Police Controller	-3.5	2. MUTCD Flagging	-4.7
3. Innvoative Flagging	-1.7	3. Police Radar	-4.0
4. MUTCD Flagging	+2.6	4. Innovative Flagging	-3.6
Cars			
1. Police Radar	-3.7	1. Police Controller	-4.6
2. Innovative Flagging	-2.4	2. MUTCD Flagging	-4.4
3. Police Controller	-2.3	3. Innovative Flagging	-3.9
4. MUTCD Flagging	+2.8	4. Police Radar	-3.5
Trucks			
1. Police Controller	-4.4	1. MUTCD Flagging	-7.2
2. Innovative Flagging	-3.4	2. Police Radar	-5.9
3. Police Radar	-3.1	3. Police Contoller	-4.8
4. MUTCD Flagging	+3.8	4. Innovative Flagging	-2.9

Analysis of the data by type of vehicle indicated that there were no statistically differences among the four treatments for cars only or for trucks only.

The results of the data for the two-lane closure are somewhat surprising when compared to the one-lane closure. For example, it is difficult to understand why the MUTCD Flagging treatment would be effective for two-lane closures and not effective for one-lane closures. One theory is proposed: it appears that an experimental artifact may have biased the results at Station C during the two-lane closures. For example, it is possible that drivers were forced to reduce speeds in order to merge into one open lane during the two-lane closures. Thus, the speed reductions were tempered by things other than the speed control treatments.

Table 5. Average Speed Changes (MPH) - Base Vs. Early Periods

	One-Lane Closure			Two-Lane Closure		
	Station A	Station B	Net Change Station B	Station A	Station B	Net Change Station B
All Vehicles						
MUTCD	-3.9	-3.7	+0.2	-3.1	+3.6	+6.7
Police with Radar	-1.1	-3.5	-2.4	+0.7	+4.3	+3.6
Police Controller	+2.9	-2.2	-5.1	+1.0	-5.3	-6.3
Innovative Flagging	-2.8	-1.4	+1.4	+2.3	-4.1	-6.4
Cars						
MUTCD	-3.5	-3.6	-0.1	-2.7	+3.2	+5.9
Police with Radar	-1.3	-3.9	-2.6	+0.5	+4.2	+3.7
Police Controller	+2.3	-2.0	-4.3	+0.7	-5.6	-6.3
Innovative Flagging	-2.1	-2.1	0.0	+2.6	-4.1	-6.7
Trucks						
MUTCD	-6.8	-2.7	+4.1	-2.1	+4.3	+6.4
Police with Radar	-2.0	-1.9	+0.1	+1.7	+5.2	+3.5
Police Controller	+3.8	-3.1	-6.9	-0.1	-5.6	-5.5
Innovative Flagging	-1.4	+1.9	+3.3	+1.4	-3.2	-4.6

Short-Term Exposure at Station B

Station B was analyzed using the same procedures as Station C. Both Early and Late speed control treatment effects were evaluated with adjustment for differences in Station A speeds. Tables 5 and 6 summarize the speed changes at Stations A and B, the net adjusted speed change, and the ranking and results of statistical tests of significance of these net changes.

One-Lane Closure

For the one-lane closure for all vehicles (cars and trucks), all treatments showed a statistically significant change in net speeds. The Police Controller and the Police Radar treatments both significantly reduced net speeds (-5.1 and -2.4 mph). The Police Controller treatment resulted in a significantly lower net speed than the Police Radar treatment. The MUTCD Flagging and the Innovative Flagging treatments resulted in increases in net speed (+0.2 and +1.4 mph). The changes in speed resulting from the Police Radar, MUTCD Flagging, and Innovative Flagging treatments were not considered to be of practical significance (i.e., essentially, there were no changes in net speeds with these treatments).

For cars and trucks analyzed separately, the Police Controller was effective in reducing speeds. The Police Radar treatment was effective in reducing car speeds, but resulted in no effect for trucks. The Innovative Flagging and the MUTCD Flagging treatments were found to be equal in effect. No net speed change was found for cars, and speed increases were found for trucks.

Two-Lane Closure

For the two-lane closure, the Innovative Flagging and the Police Controller resulted in very significant net reductions in speed (-6.4 and -6.3 mph). The MUTCD Flagging and the Police Radar resulted in significant increases in net speeds (+6.7 and +3.6 mph). The increase in speed using the MUTCD Flagging treatment was significantly higher than the increase with the Police Radar treatment.

Long-Term Exposure at Station B

Results of the speed changes at Stations A and B, the net speed changes (adjusted speeds), and the ranking and results of statistical tests of significance are summarized in Tables 7 and 8.

Table 6. Ranking Within One- or Two-Lane Closures
Station B Early Treatment Effect

One-Lane Closure		Two-Lane Closure	
All Vehicles			
1. Police Controller	-5.1	1. Innovative Flagging	-6.4
2. Police Radar	-2.4	2. Police Controller	-6.3
3. MUTCD Flagging	+0.2	3. Police Radar	+3.6
4. Innovative Flagging	+1.4	4. MUTCD Flagging	+7.8
Cars			
1. Police Controller	-4.3	1. Innovative Flagging	-6.7
2. Police Radar	-2.6	2. Police Controller	-6.3
3. MUTCD Flagging	-0.1	3. Police Radar	+3.7
4. Innovative Flagging	0.0	4. MUTCD Flagging	+5.9
Trucks			
1. Police Controller	-6.9	1. Police Controller	-5.5
2. Police Radar	+0.1	2. Innovative Flagging	-4.6
3. Innovative Flagging	+3.3	3. Police Radar	+3.5
4. MUTCD Flagging	+4.1	4. MUTCD Flagging	+6.4

Table 7. Average Speed Changes (MPH) - Base Vs. Late Period

	One-Lane Closure			Two-Lane Closure		
	Station A	Station B	Net Change Station B	Station A	Station B	Net Change Station B
All Vehicles						
MUTCD	-3.2	+1.2	+4.4	-2.4	+0.9	+3.3
Police with Radar	-1.4	-0.9	+0.5	+2.7	-2.7	-5.4
Police Controller	+2.3	0.0	-2.3	+1.7	-5.1	-6.8
Innovative Flagging	-1.6	-1.9	-0.3	+3.4	-3.3	-6.7
Cars						
MUTCD	-2.2	+1.1	+3.3	-3.4	+0.6	+4.0
Police with Radar	-1.5	-1.2	+0.3	+2.0	-3.0	-5.0
Police Controller	+1.7	+0.6	-1.1	+0.9	-5.1	-6.0
Innovative Flagging	-1.4	-2.7	-1.3	+3.2	-3.3	-6.5
Trucks						
MUTCD	-6.8	+2.7	+9.5	+2.4	+1.6	-0.8
Police with Radar	-1.8	+0.3	+2.1	+1.0	-0.5	-1.5
Police Controller	+3.9	-3.1	-7.0	+3.9	-5.4	-9.3
Innovative Flagging	-0.4	+1.4	+1.8	+1.4	-2.9	-4.3

Table 8. Ranking Within One- or Two-Lane Closures
Station B Late Treatment Effect

One-Lane Closure		Two-Lane Closure	
All Vehicles			
1. Police Controller	-2.3	1. Police Controller	-6.8
2. Innovative Flagging	-0.3	2. Innovative Flagging	-6.7
3. Police Radar	+0.5	3. Police Radar	-5.4
4. MUTCD Flagging	+4.4	4. MUTCD Flagging	+3.3
Cars			
1. Innovative Flagging	-1.3	1. Innovative Flagging	-6.5
2. Police Controller	-1.1	2. Police Controller	-6.0
3. Police Radar	+0.3	3. Police Radar	-5.0
4. MUTCD Flagging	+3.3	4. MUTCD Flagging	+4.0
Trucks			
1. Police Controller	-7.0	1. Police Controller	-9.3
2. Innovative Flagging	+1.8	2. Innovative Flagging	-4.3
3. Police Radar	+2.9	3. Police Radar	-1.5
4. MUTCD Flagging	+9.5	4. MUTCD Flagging	-0.8

One-Lane Closure

For the one-lane closure for all vehicles, only the Police Controller resulted in a statistically significant reduction in net speed. However, the -2.3 mph speed change was not of practical significance. The Innovative Flagging and the Police Radar treatments had no effect on net speeds. The MUTCD Flagging resulted in a statistically and practically significant increase in net speeds. The change was +4.4 mph. For cars, none of the treatments resulted in any practical changes in net speed. However, for trucks, the Police Controller resulted in a -7.0 mph change in speed while the MUTCD Flagging treatment resulted in a +9.5 mph change in speed.

Two-Lane Closure

For the two-lane closure, all treatments except the MUTCD Flagging treatment reduced net speeds significantly. The Police Controller, Innovative Flagging, and Police Radar resulted in net speed changes of -6.8, -6.7, and -5.4 mph. The MUTCD Flagging resulted in a 3.3 mph increase in speed. The results with respect to decreases and increases in net speeds were repeated when only the car data were analyzed. However, for trucks only, the Police Radar and the MUTCD Flagging resulted in no significant change in net speeds.

Long-Term Exposure at Station C

The speed changes at Stations A and C between the Base and Late treatment periods and the net speed change for Station C adjusted for Station A speeds are listed in Table 9. Rankings of the speed control treatments and the results of statistical tests of significance among these treatments are shown in Table 10. If there was a long-term speed control treatment effect, the results of this analysis should agree with those of the Early treatment effect at Station C.

One-Lane Closure

For the late period sample with all vehicles (cars and trucks) and one-lane closure, the rankings of the treatments agree with the Early treatment analysis. However, the data indicated that the Police Radar treatment improved with time. The net change in average speed with the Police Radar treatment was -8.4 mph. This reduction is also statistically significantly better than the Police Controller treatment which experienced a net speed change of -3.3 mph during the Late time period. Neither Innovative Flagging nor MUTCD Flagging were significant in reducing speeds and, whereas there were speed increases for both of these treatments, the increases were neither statistically nor practically significant. (Note that the net speed increase for the MUTCD Flagging during the Early period was statistically significant).

For cars only, all treatments were significantly different from each other and for trucks only, the net speed changes for all treatments were significant but equal.

Two-Lane Closure

For the two-lane closure, all speed control treatments resulted in a net average speed reduction during the Late period. However, the speed reduction for the Police Radar treatment reduced net speeds by an even greater amount than in the Early treatment period. When vehicle types were separated, however, this improvement was not statistically significant for cars. For trucks, the net speed change for the MUTCD Flagging became significantly higher than during the Early period. The sample sizes for trucks in this analysis were extremely low for some treatments, however, and the variability was higher (as evidenced in the results of statistical equality between the Police Radar and Innovative Flagging treatments despite a 3.3 mph difference).

Table 9. Ranking Within One- or Two-Lane Closures
Station C Late Treatment Effect

One-Lane Closure		Two-Lane Closure	
All Vehicles			
1. Police Radar	-8.4	1. Police Radar	-6.4
2. Police Controller	-3.3	2. MUTCD Flagging	-3.8
3. MUTCD Flagging	+0.8	3. Police Controller	-3.3
4. Innovative Flagging	+1.4	4. Innovative Flagging	-3.0
Cars			
1. Police Radar	-8.7	1. Police Radar	-5.8
2. Police Controller	-2.4	2. Police Controller	-3.5
3. MUTCD Flagging	-0.4	3. Innovative Flagging	-3.2
4. Innovative Flagging	+1.2	4. MUTCD Flagging	-2.3
Trucks			
1. Police Controller	-6.4	1. MUTCD Flagging	-10.6
2. Innovative Flagging	-4.9	2. Police Radar	-4.1
3. Police Radar	+0.1	3. Police Controller	-1.5
4. MUTCD Flagging	+6.2	4. Innovative Flagging	-0.8

Table 10. Average Speed Changes (MPH) - Base Vs. Late Period

	One-Lane Closure			Two-Lane Closure		
	Station A	Station C	Net Change Station C	Station A	Station C	Net Change Station C
All Vehicles						
MUTCD	-3.2	-2.4	+0.8	-2.4	-6.2	-3.8
Police with Radar	-1.4	-9.8	-8.4	+2.7	-3.7	-6.4
Police Controller	+2.3	-1.0	-3.3	+1.7	-1.6	-3.3
Innovative Flagging	-1.6	-0.2	+1.4	+3.4	+0.4	-3.0
Cars						
MUTCD	-2.2	-2.6	-0.4	-3.4	-5.7	-2.3
Police with Radar	-1.5	-10.2	-8.7	+2.0	-3.8	-5.8
Police Controller	+1.7	-0.7	-2.4	+0.9	-2.6	-3.5
Innovative Flagging	-1.4	-0.2	+1.2	+3.2	0.0	-3.2
Trucks						
MUTCD	-6.8	-0.6	+6.2	+2.4	-8.2	-10.6
Police with Radar	-1.8	-8.2	-6.4	+1.0	-3.1	-4.1
Police Controller	+3.9	-1.0	-4.9	+3.9	+2.4	-1.5
Innovative Flagging	-0.4	-0.3	+0.1	+1.4	+0.6	-0.8

SUMMARY OF RESULTS

The basic theory is that the speed reduction treatments applied at Station B where all the freeway lanes are opened to traffic will result in reduced speed at Station C, located in the area of active construction. Lane closure refers to the reduction of the number of lanes opened to traffic at Station C only. A summary of results is presented below.

Station C With One-Lane Closure

The results indicate that the Police Radar and the Police Controller were effective in reducing vehicle speeds in both the short-term (about 3 days) and the long-term (more than two weeks) after the speed control treatments were implemented on the freeway work sites studied. The Innovative Flagging speed control treatment did elicit a small decrease in speeds in the short-term, but the decrease was less than 2 mph and was considered to be practicaly insignificant. In the long-term, the Innovative Flagging did not result in speed reductions at Station C. The MUTCD Flagging treatment actually resulted in a small increase in speed in the short- and long-term.

Station C With Two-Lane Closure

Significant reductions in speeds were experienced in both the short-term and long-term for all four speed control treatments when two of the three freeway lanes were closed. The amount of speed reductions were the same statistically for each treatment, with the exception that the Police Radar treatment resulted in a greater long-term speed reduction.

The results of the data for the two-lane closure are somewhat surprising when compared to the one-lane closure. For example, it is difficult to understand why the MUTCD Flagging treatment would be effective for two-lane closures and not effective for one-lane closures. One possible explanation is that an experimental artifact may have biased the results at Station C during the two-lane closures. For example, it is possible that drivers were forced to reduce speeds in order to merge into one open lane during the two-lane closures. Thus, the speed reductions were tempered by things other than the speed control treatments.

Station B With One-Lane Closure at C

The Police Controller was the only speed control treatment that resulted in a significant (both statistically and practically) short-term speed reduction at Station B. The Police Controller also resulted in a long-term speed reduction; however, the reduction was only 2.3 mph which was not considered to be of practical significance. There was essentially no long-term speed reductions for the Police Radar or the Innovative Flagging treatments. In the long-term, the MUTCD Flagging resulted in an increase in speed.

Station B With Two-Lane Closure at C

Significant long-term speed reductions were experienced at Station B when the Police Controller, Police Radar, or Innovative Flagging treatments were used. There was a significant long-term speed increase during the MUTCD Flagging operations.

CONCLUSIONS

The results of this research indicate that the long-term — more than two weeks — application of all the tested speed control treatments can derive significant reduction in traffic speed through the work area in highway construction zones. However, the effectiveness of the treatments appear to depend on the number of lanes that remain opened to traffic in the work area. The flagging techniques were effective in reducing speed in the work area where there was one lane open and two lanes closed. It should be noted, however, that the entire data collection effort was conducted under ideal traffic conditions, with level of service A. Thus during one-lane closures drivers still had unlimited maneuverability and sufficient advance warning by the basic construction traffic control devices to enable them to merge into the two opened lanes without the need to reduce speed. This might explain why the flagging methods are less effective during one-lane closures than during two-lane closures . The two-lane closures result in higher lane volume and less maneuverability in the approach to the work area. It stands to reason that at lower levels of service — higher lane volumes — the flagging methods could experience increased effectiveness during one-lane closures.

The law enforcement methods demonstrated strong long term speed reduction capability. This finding, however, must be evaluated with due consideration given to the normal level of law enforcement activity on the freeways. In this research, all the study sites were located on facilities where there was already an exceptionally high level of police patrol. Thus most motorists were already aware of the high probability of being ticketed and saw compliance with speed control as the convenient option. Jurisdictions where a reputation for enforcing the speed limit is not well known may not obtain significant reduction in speed via law enforcement methods. Consistent enforcement of speed limits will facilitate the effectiveness of law enforcement speed control techniques.

RECOMMENDATION

When this research began, the study team contacted several states seeking their cooperation in implementing the data collection on construction sites. Every contacted state indicated that speeding through highway construction zones was a serious continuing problem and most were skeptical about any solution. This skepticism appears to be rooted in the scarcity of resources for effective implementation of speed control methods and the inability to establish an integrated administrative mechanism to enable the speed reduction methods of this research to be included in construction specifications as part of the traffic control plan. The engineer responsible for developing the traffic control plan should select a safe operating speed for the work zone and determine the need for speed reduction measures. Noting the effectiveness of utilizing police officers for speed control, state and local Departments of Transportation are encouraged to make special contractural provisions for their implementation into the traffic control plans. These provisions should include procedures for obtaining off-duty police personnel for the work sites, compensation, list of contact persons, applicable union requirements, scheduling, dress and equipment.

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APPENDIX A

STATISTICAL METHODS

The statistical methods described in this section were used to answer the following questions:

1. Is there a significant treatment effect on driver speeds between the base and early treatment periods at Station C adjusted for differences in driver speeds at Station A?

2. Is there a significant treatment effect on driver speeds between the base and late treatment periods at Station C adjusted for differences in driver speeds at Station A?

3. Is there a significant treatment effect on driver speeds between the base and early treatment periods at Station B adjusted for differences in driver speeds at Station A?

4. Is there a significant treatment effect on driver speeds between the base and late treatment periods at Station B adjusted for differences in driver speeds at Station A?

A two-step procedure was used to answer these questions. A two-factor analysis of variance model was used including the factors of treatment type (SITE), tretment period (TRT) and treatment type-by-period interaction (TRT*SITE). Since each site in the study represented a different treatment, the term SITE was used in the computer analysis to denote treatment type differences, whereas the term TRT denoted treatment period differences. In any case, the only term of interest in this study is the interaction term. This term measures the treatment effects relative to the base periods. Specifically, it tests the hypothesis:

$$H: (DIFF)_i = (DIFF)_j$$

where DIFF is the difference between the base period mean speed and the treatment period mean speed (early or late) for all treatment pairs i and j (i and j representing treatments MUTCD Flagging, Police Radar, Police Controller and Innovative Flagging). There are three independent pairs (contrasts) which can be made (e.g., MUTCD Flagging vs Police Radar, MUTCD Flagging vs Police Controller, MUTCD Flagging vs Innovative Flagging) corresponding to the three degrees of freedom for the interaction term in the Analysis of Variance. The main effect terms in this analysis are not of practical interest since, for example, the SITE effect tests the equality of treatment types averaged over the base and treatment periods which confounds the treatment effect with the period effect. The same is true for the TRT main effect which confounds site differences with treatment differences. In other words, the interaction term is the only statistically valid term to test since this represents a measure of treatment effect unconfounded by site or driver population differences.

If the interaction term in the above model is not significant, there are no treatment differences and the analysis is complete. If, however, the interaction term is significant, then the next step is to determine which treatments are different, and the direction of the difference (i.e., were driver speeds significantly reduced or did they increase due to the treatment?). This is done by ranking the mean treatment speeds and performing multiple pairwise comparisons on the ranked means using the Scheffe' method of multiple comparison. The Scheffe' test is conducted at the .01 level of significance to produce an overall .05 level of significance on the test conclusions. Scheffe' test results are presented in Table A-1. The SAS Anlaysis of Variance procedure does not provide an automated mutliple comparison test for any model parameters except the main effects, hence these tests were computed manually.

TABLE A-1. SCHEFFE TEST RESULTS - STATION C

	One-Lane				Two-Lane			
EARLY TRT	n	Mean	Diff	F*	n	Mean	Diff	F*
All Lengths	800	-4.0	0.5	1.5	No significant interaction.			
	871	-3.5	1.8	6.1*	All treatments are equal.			
	1173	-1.7	4.3	15.5*				
	1082	2.6						
				√MSE = 6.6				
Cars	600	-3.7	1.3	3.8*	No significant interaction.			
	900	-2.4	0.1	.3	All treatments are equal.			
	570	-2.3	5.1	14.9				
	940	2.8						
				√MSE = 6.4				
Trucks	120	-4.4	1.0	1.1	No significant interaction.			
	117	-3.4	0.3	.3	All treatments are equal.			
	200	-3.1	6.9	6.9*				
	140	3.8						
				√MSE = 7.1				
LATE TRT								
All Lengths	350	-8.4	5.1	12.6*	500	-6.4	-2.6	6.4*
	970	-3.3	4.7	16.7*	600	-3.8	-0.5	1.2
	1200	1.4	0.6	1.8	520	-3.3	0.3	0.7
	650	0.8			120	-3.0		
				√MSE = 6.5				√MSE = 6.7
Cars	300	-8.7	6.3	14.7*	400	-5.8	1.3	2.8
	850	-2.4	2.0	5.7*	445	-3.5	0.3	0.4
	560	-0.4	1.6	4.4*	82	-3.2	0.9	2.0
	700	1.2			470	-2.3		
				√MSE = 6.4				√MSE = 6.5
Trucks	120	-6.4	1.5	1.5	82	-10.6	6.5	5.9*
	80	-4.9	5.0	5.9*	105	-4.1	2.6	2.3
	400	0.1	6.1	7.2*	75	-1.5	0.7	0.5
	80	6.2			45	-0.8		
				√MSE = 6.9				√MSE = 7.4

APPENDIX B

USER GUIDE: SPEED CONTROL AT WORK ZONES

NEED FOR SPEED CONTROL

Numerous accident studies have identified excessive vehicle speed as a major contributor to accidents in highway work zones. Hence to meet the safety needs of a work zone, speed control is an important facet of the traffic control plan that needs to be addressed.

The basic safety principles governing the design speeds of permanent roadways and roadsides should also govern the design speed of work zones. The goal should be to route traffic through such areas with geometrics and traffic control devices comparable to those for normal highway situations. Where possible the design speeds for the work zone traffic control plan should correspond with the posted speed limit of the highway. Still, in order to maintain acceptable levels of safety, work zone conditions may dictate the need for a speed reduction of the vehicles traveling through the work zone.

Traffic control in work sites should be designed on the assumption that motorists will reduce their speeds only if they clearly perceive a need to do so. Reduced speed zoning should be avoided as much as possible. Circumstances, however, such as frequent and abrupt changes in geometrics (i.e., lane narrowing, dropped lanes, or main roadway transitions) or the safety of construction operations (e.g., slow moving and crossing construction vehicles, and close proximity of construction workers and vehicles to through traffic) may dicatate a need for speed reduction.

SELECTION OF A REASONABLE SPEED

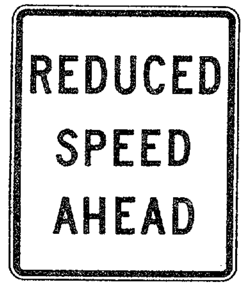
After it has been determined that reduced speeds are desirable and practical, a speed should be selected which is reasonable for the conditions. Among the conditions that need to be given consideration when selecting a reduced speed are existing speeds, work zone design speeds (determined by horizontal curvature, sight distance, superelevation, etc.) and work zone conditions (interaction of workers and equipment with traffic stream). It is important that the selected speed is not significantly lower than drivers reasonably expect or will tolerate. If an unreasonably low speed is sought by the highway agency, drivers will quickly lose respect for the speed control effort. The loss of credibility and respect will result in reduced effectiveness of the speed control technique at the site.

SPEED REDUCTION

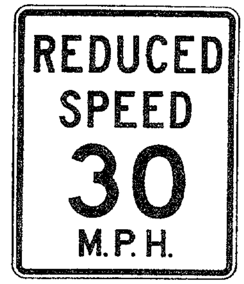
Speed reduction can be accomplished by using one of two methods: reducing the regulatory speed limit and advisory maximum speed warnings.

In the first case the speed limit is reduced to the desired level. Reducing the regulatory speed limit would likely be justified for only long term and long distance construction projects. Proper authority and approval is needed before changing the current speed limit.

The Manual on Uniform Traffic Control Devices (see Section 2B-10, 28-14 and 6B-6) indicates the required signing for regulatory speed limits and speed limit reductions. Two appropriate reduced speed signs are illustrated on the right. The state or local police who are charged with enforcing these regulations should be notified of the speed reduction.

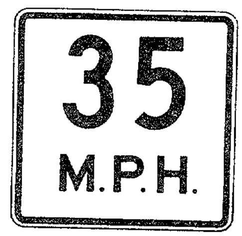


R2-5a

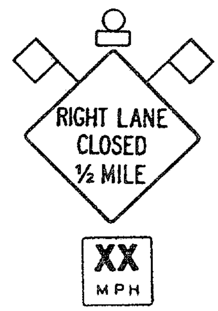


R2-5b

A more common procedure is to use an Advisory Speed plate (W13-1, MUTCD Sec 6B-34) in conjunction with a warning sign as illustrated on the right. It is used to recommend the maximum speed through the hazardous area. Except in emergencies, an Advisory Speed plate shall not be erected until the recommended speed has been determined by the authority in charge of the highway.



W13-1



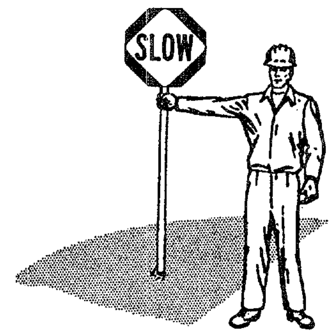
Unfortunately, motorists do not always slow down to the posted work zone speed limits or maximum speed advisory. When utilizing regulatory or advisory signing as speed control, more positive measures may be needed to realize the desired speed. Recent studies have found that the use of hand signaling devices and/or law enforcement officers are effective methods of accomplishing reduction of speeds in work zones.

HAND SIGNALING DEVICES

Hand signaling devices such as STOP/SLOW paddles and red flags can be effective in reducing speed and controlling traffic through work zones. The sign paddle bearing the clear messages STOP or SLOW provide motorists with more positive guidance than red flags and, thus, are the primary hand signaling device. The alternative methods for alterting or slowing traffic are noted below:

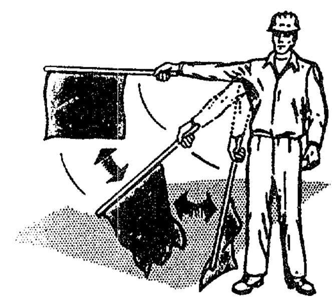
Sign Paddle

The flagger shall face traffic with the SLOW sign paddle held in a stationary position with the arm extended horizontally away from the body as illustrated here.



Red Flag

The flagger shall face traffic and slowly wave the flag in a sweeping motion of the extended arm from the shoulder level to straight down without raising the arm above the horizontal position as illustrated here.



For greater emphasis, in addition to the standard MUTCD procedures described above, the flagger can also motion to traffic with his free hand to slow down and then to point at a nearby speed limit sign. This "innovative" technique, demonstrated in Figure B-1, has been shown to be effective where the traffic control results in one through lane in the construction area.

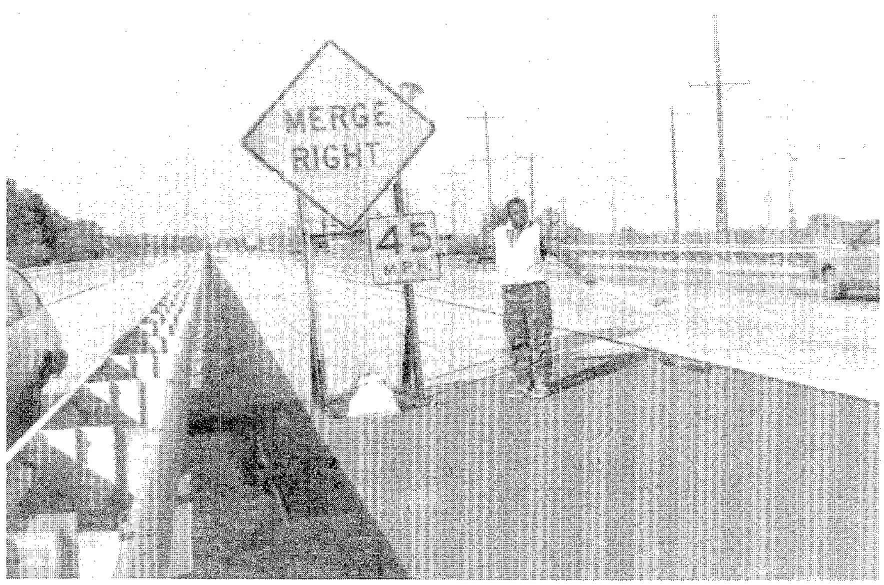
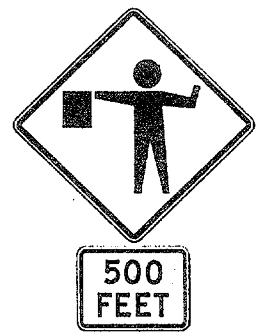


Figure B-1. "Innovative" MUTCD Flagging

The MUTCD stresses the need for qualified personnel to be used as flaggers. To realize the maximum potential for speed reduction, flaggers should be intelligent, alert, and trained in proper flagging techniques.

The flagger must at all time be clearly visible to approaching traffic for a distance sufficient to permit traffic to reduce speed before entering the worksite. This distance is related to approach speed and physical conditions at the site; however, a distance of 200 to 300 feet is desirable.



W20-7a
36" x 36"
Supplemental Plate
24" x 18"

The use of orange clothing such as a vest, shirt, or jacket shall be required for flaggers. In positioning flaggers consideration must be given to maintaining color contrast between the work area background and the flagger's protective garments.

Flaggers should be adequately protected and preceded by proper advance warning signs including the Advanced Flagger Sign (MUTCD Section 6B-20) and the optional distance plate.

LAW ENFORCEMENT OFFICERS

While studies and experience have determined the use of flaggers as an effective method in reducing speed, using police officers has been documented as significantly more effective in reducing speeds and therefore their use should be given strong consideration. Two methods of utilizing police officers for speed control that have beeen tested and determined very effective are:

Stationary Police Cruiser With Lights and Radar On

This technique requires a marked patrol car with cruiser lights and a radar device in full view. See Figure B-2. The policeman can and should remain in the vehicle in order to alert speeders of this readiness for pursuit. For maximum effectiveness, the patrol car should be highly visible to approaching traffic.

Figure B-2. Stationary Police Cruiser With Lights and Radar On

Police Traffic Controller

A uniformed officer standing on the side of the road near a speed limit sign manually motions the traffic to slow down. The policeman need not wear special flagman attire. See Figure B-3.

Figure B-3. Police Traffic Controller

The most effective of the police officer methods is the method utilizing the patrol car with cruiser lights and radar in operation. The officer may occasionally need to chase a speed limit violator, but generally the patrol car should remain in place.

The practice of using law enforcement officers varies widely. In some states legislation has been enacted which prohibits anyone but a uniformed police officer from directing traffic. In other states strong labor unions have been effective in keeping contractors from hiring part-time police officers for traffic control duties. Some police departments are very cooperative in lining up policeman for off-duty part-time employment. In certain jurisdictions on-duty police will be provided, if needed. Sometimes, however, they may be called off the job to attend to higher priority police work.

RESPONSIBILITY AND CONTRACTURAL ISSUES

Good speed control starts with a well thought out traffic control plan. The engineer responsible for developing the traffic control plan should select a safe design speed for the work zone and determine the need for speed reduction measures.

Maintenance of the plan should be conducted by a Safety Inspector or other responsible official for the work site. During the course of the project, traffic speeds and accidents should be continually monitored by the safety inspector to insure the objectives of the plan are realized.

As part of the traffic control plan, safe speeds (as indicated in the traffic control plan and or as determined by the safety inspector) need to be maintained and if necessary enforced. If a need for additional speed control has been identified, traffic control plans and contract documents should contain the flexibility to be easily modified to include such speed control methods as the use of police officers and the use of hand signal devices. For instance, a unit bid item approach for traffic safety items would allow for all contigencies and insure that motorist's safety interests are not compromised.

Noting the effectiveness of utilizing police officers for speed control, State and local Departments of Transportation are encouraged to make special contractural provisions for their implementation into the Traffic Control Plan. These provisions should include procedures for obtaining off-duty police personnel for worksite traffic control during non-emergency periods. The procedures should spell out the process for obtaining the services of off-duty police officers, whom to contact and how; including such items as the amount of compensation to be paid; union requirements, if any; and the appropriate dress and equipment.

SUMMARY

As with all traffic control efforts, any effort to reduce work zone speeds should be founded on an identifiable need. Speed reduction should be aimed at decreasing the number and/or severity of work zone accidents, or the potential for accidents at sites where speed-related potential hazards exist.

Speed control abuse and misuse at a work zone can render a speed reduction attempt ineffective and can damage the credibility of work zone speed reduction effforts in general. Abusive practices include using unreasonably low speed limits and leaving reduced speed limits in place after the work activity is removed.

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