Effectiveness of Steady-Burn Lights for Traffic Control in Tangent Sections of Highway Work Zones

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Examined in this study is the effectiveness of Type *C* steady-burn lights on drums marked with high intensity (Type *G*) reflective sheeting in tangent sections of highway construction work zones. The study was performed on several rural, unlighted four-lane divided highways, including a freeway. Curved and tapered sections of highways were excluded from the study. The measures of effectiveness included speed, lateral placement, acceleration noise, weaving, traffic conflict, and driver preference. Right and left lane closures were separately examined. Study results indicated that steady-burn lights on drums marked with high-intensity reflective sheeting have little effect, if any, on driver behavior in tangent sections of rural divided highways. The study recommended that the use of steady-burn lights on drums marked with high-intensity reflective sheeting in tangent sections of construction work zones in rural divided highways including Interstate freeways be discontinued.

A highway construction work zone creates a conflicting situation for vehicular traffic and work activity. In Ohio, the *Traffic Control Application Standards Manual* (*1*) and the Ohio *Construction and Materials Specifications* (*2*) require drums in highway construction work zones to have Type *G* (also known as high-intensity) reflective sheeting, and Type *C* steady-burn lights during lane closures at night. However, the effects of steady-burn lights used in conjunction with high-intensity reflective sheeting have not been understood.

The objective of the study was to examine the effects of steady-burn lights on drums with high-intensity reflective sheeting in tangent sections of highway construction work zones. The study was limited to rural unlighted four-lane divided highways including a freeway. Curved and tapered sections were excluded from the study. The lights were evaluated under dry, rainy, and foggy weather conditions.

LITERATURE REVIEW

National Cooperative Highway Research Program Report 236 (*3*) examined the effectiveness of selected traffic control devices, including steady-burn lights. The results of the NCHRP study were not particularly applicable in Ohio because Ohio uses drums with high-intensity reflective sheeting in work zones, not the Type I barricades with engineering grade sheeting as tested in the study.

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A study by the New Jersey Department of Transportation (DOT) (*4*) recommended switching from steady-burn lights to 5- × 10-in. yellow reflectors for delineating temporary concrete barriers in construction work zones. A study by the Kansas DOT (*5*) found that at least 29 states used steady-burn lights in construction zones, but 9 did not. A Virginia study (*6*) found no difference in vehicle placement and in speed using the steady-burn lights or the reflectorized panels on top of concrete barriers. A study by the Wisconsin DOT (*7*) found that Type *H* sheeting on barrels outperformed yellow warning lights and that therefore the lights could be omitted. Additionally, studies by the Wisconsin and New York DOTs found that when vehicles strike drums, battery-powered lights fly off, crashing into windshields and flying apart at high speeds. However, none of the previous studies examined the effectiveness of steady-burn lights on drums marked with high-intensity reflective sheeting.

MEASURES OF EFFECTIVENESS

This study is based on an examination of the driving behavior of a sample of driver subjects who were asked to drive an instrumented automobile in highway construction work zones. The measures of effectiveness are as follows:

1. *Speed*. The speed of the vehicle for each subject was measured continuously at 1.0-sec intervals over a length of ½ to ¾ mi of tangent sections of construction work zones.
2. *Lateral Placement*. The distance maintained by the subject between the vehicle and the longitudinal pavement markings was recorded continuously at ½-sec intervals.
3. *Acceleration Noise*. The acceleration noise used to determine the smoothness of the trip was calculated using the equation derived by Drew et al. (*8*).
4. *Weaving*. Weaving is defined as the rate of change in lateral displacement per unit time. The average weaving during the trip period consisting of n intervals is expressed as:

$$W_{avg} = \sum[ABS(X_i - X_{i-1})]/n$$

W = weaving,
ABS = absolute value,
X_i = lateral placements of the vehicle at times t_i (in this study, t was measured in units of ½ sec),
X_{i-1}, = lateral placements of the vehicle at times t_{i-1}, and
n = number of intervals

5. *Traffic Conflict*. A traffic conflict is defined as an unusual or drastic action such as braking to which a motorist may have to resort while driving a vehicle in a highway construction work zone.

6. *Driver Preference*. Immediately after the completion of the tests, each driver was asked to fill out a questionnaire describing age, sex, vision, education, driving experience, and mileage typically driven in a year. If subjects noticed the absence of steady-burn lights, they were asked to fill out a second questionnaire providing a subjective evaluation of the steady-burn lights.

DATA COLLECTION

An instrumented automobile was used for collecting speed and lateral placement data in several highway construction work zones. A distance measuring instrument was installed in the automobile. The distance traveled by the automobile at 1.0-sec intervals was downloaded into a portable personal computer. The automobile was equipped with a video camera installed on the roof.

The field data were collected in three rural highway construction work zones, including an Interstate freeway. Each highway was a limited access, unlighted four-lane divided highway with a wide grass median. The posted speed limits were either 65 or 55 mph. The test sections had no significant grade, and were generally ½ to ¾ mi long. Drums marked with high-intensity reflective sheeting were erected at 100- to 120-ft spacings. Some of the drums and pavement markings were dirty or worn and some were in relatively good condition.

The age group of driver subjects was divided into six categories from 16 to 75 years old. The sample size for the study was 132, with the number of driver subjects for each type of lane closure being 66.

None of the driver subjects were told why they were asked to drive the automobile. The first set of data for each subject was collected in the construction work zone in late afternoon. Then, during hours of complete darkness, the first set of nighttime data was collected with steady-burn lights placed on the drums. During the second set of nighttime data collection, the steady-burn lights were covered, without the subjects' knowledge, with black-surfaced wallpaper bags.

DATA ANALYSIS AND RESULTS

The data for right- and left-lane closures were separately analyzed (Table 1). Several hypotheses for speed, lateral placement, acceleration noise, and weaving were tested by performing t-tests for means and F-tests for variances at 5 percent level of significance. Additionally, paired t-tests were performed for these measures of effectiveness. The results of the analysis are described in the following paragraphs.

Speed

First, the mean speeds and speed variances at each site were separately tested. Then the data for all sites were combined to perform the remaining tests. Generally, the tests showed that there were no significant differences between the mean speeds or speed variances during the three periods. In a small number of cases in which the null hypotheses were rejected, the differences were too small to have any practical significance. The data were then categorized by weather conditions, ages of driver subjects, sex, and subjects who noticed the absence of steady-burn lights. The hypotheses were tested for each category. In general, all null hypotheses were accepted, indicating that the mean speeds or speed variances were not significantly different.

Additionally, paired t-tests were performed to examine whether the mean speeds between any two periods were significantly different. Similar results as those previously described were found from the tests (Table 2).

Lateral Placement, Acceleration Noise and Weaving

The statistical tests for lateral placement, acceleration noise, and weaving followed the same procedures as for mean speeds described in the previous section. In general, the null hypotheses were accepted, indicating that the means and variances are not significantly different. In some cases, the null hypotheses were accepted, indicating that the differences were significantly different. However, the differences were too small to have any practical importance.

Traffic Conflict

The tests showed that the absence of steady-burn lights on the drums did not cause any unusual or drastic action on the part of the subjects.

Driver Preferences

The results showed that only 13 subjects, or 10 percent, noticed the absence of steady-burn lights on drums during the second nighttime experiments. These subjects were asked to respond to specific questions for right- and left-lane closures on a scale of 1 to 10 as follows:

0	1	2	3	4	5	6	7	8	9	10
Strongly Disagree		Disagree			Undecided		Agree			Strongly Agree

In general, the subjects were undecided if their drives were affected by the absence of lights on the drums, if the drums did not provide a good path for them to drive through the work area, and if the absence of lights on the drums made them feel unsafe. Their responses lay between 5.0 and 5.9.

CONCLUSIONS AND RECOMMENDATIONS

The study has shown that steady-burn lights have little effect, if any, on driver behavior in tangent sections of rural, unlighted divided highways including Interstate freeways. It indicated that the high-intensity reflective sheeting outperformed the steady-burn lights and hence the presence or absence

TABLE 1 Average Speed, Lateral Placement, Acceleration Noise, and Weaving

		ALL	I-71	U.S.127	U.S.27
SPEED (MPH)	N	66	32	29	5
	SP1	53.3 (4.5)	55.9 (2.9)	50.4 (4.4)	53.7 (4.5)
	SP3	51.3 (5.2)	53.9 (3.6)	48.9 (5.4)	48.2 (6.5)
	SP5	52.4 (5.1)	54.2 (4.2)	50.7 (5.1)	50.1 (7.6)
	N	66	20	19	27
	SP2	53.2 (4.1)	55.6 (3.4)	50.2 (4.0)	53.4 (3.2)
	SP4	51.6 (4.6)	55.4 (3.5)	48.4 (3.5)	51.0 (4.1)
	SP6	51.9 (4.7)	55.1 (3.7)	48.5 (3.7)	51.9 (4.4)
LATERAL PLACEMENT (ft)	N	66	32	29	5
	LP1	0.9 (0.4)	0.9 (0.4)	0.9 (0.4)	1.0 (0.3)
	LP3	0.9 (0.4)	0.9 (0.5)	0.9 (0.4)	0.9 (0.2)
	LP5	1.0 (0.4)	0.9 (0.5)	1.0 (0.4)	1.0 (0.3)
	N	66	20	19	27
	LP2	1.5 (0.4)	1.5 (0.6)	1.3 (0.30	1.6 (0.3)
	LP4	1.5 (0.4)	1.4 (0.6)	1.5 (0.3)	1.6 (0.4)
	LP6	1.6 (0.4)	1.6 (0.6)	1.5 (0.3)	1.5 (0.3)
ACCELERATION NOISE (ft/sec^2)	N	66	32	29	5
	AC1	1.1 (0.2)	1.2 (0.2)	1.0 (0.1)	1.0 (0.0)
	AC3	1.0 (0.1)	1.1 (0.2)	1.0 (0.1)	1.0 (0.1)
	AC5	1.0 (0.2)	1.1 (0.2)	1.0 (0.1)	1.0 (0.1)
	N	66	20	19	27
	AC2	1.1 (0.2)	1.3 (0.2)	1.0 (0.2)	1.0 (0.1)
	AC4	1.0 (0.2)	1.2 (0.2)	0.9 (0.1)	0.9 (0.1)
	AC6	1.0 (0.2)	1.2 (0.3)	0.9 (0.1)	1.0 (0.1)
WEAVING (ft)	N	66	32	29	5
	WI1	1.1 (0.3)	1.3 (0.3)	0.9 (0.1)	0.8 (0.0)
	WI3	1.0 (0.3)	1.2 (0.3)	0.9 (0.1)	0.8 (0.0)
	WI5	1.1 (0.3)	1.3 (0.3)	0.9 (0.1)	0.8 (0.0)
	N	66	20	19	27
	WI2	0.9 (0.1)	1.0 (0.2)	0.8 (0.1)	0.8 (0.1)
	WI4	1.0 (0.2)	1.1 (0.2)	0.8 (0.1)	0.9 (0.1)
	WI6	0.9 (0.2)	1.1 (0.2)	0.8 (0.1)	0.9 (0.1)

For key to the variables, see TABLE 2.

TABLE 2 ***T*-Test and Paired *T*-Test for Average Speed (5 Percent Level of Significance)**

T-TEST			PAIRED T-TEST	
HYPOTHESES	MEAN	VARIANCE	HYPOTHESES	MEAN
SP1=SP3	S	NS	SP1-SP3 = 1 MPH	NS
SP1=SP5	NS	NS	SP1-SP5 = 1 MPH	NS
SP3=SP5	NS	NS	SP3-SP5 = -1 MPH	NS
SP2=SP4	NS	NS	SP2-SP4 = 1 MPH	NS
SP2=SP6	NS	NS	SP2-SP6 = 1 MPH	NS
SP4=SP6	NS	NS	SP4-SP6 = -1 MPH	NS

Key to variables

NS = No significant difference
SP = Speed
AC = Acceleration noise
( )= Standard deviation
S = Significant difference
LP = Lateral placement
WV = Weaving
N = Sample size

1,3 and 5 refer to right lane closure during daytime, nighttime with steady burn lights and nighttime without steady burn lights respectively.

2,4 and 6 refer to left lane closure during daytime, nighttime with steady burn lights and nighttime without steady burn lights respectively.

of the lights seemed to have little impact on the subjects' speed, lateral placement, acceleration noise, or weaving. There was little difference in the mean speeds among right- and left-lane closures. The tests showed that the subjects relied heavily on pavement markings for delineation, and to a lesser extent on drum placements.

The mean lateral placement for right-lane closures was about 60 percent higher than for left-lane closures. The results showed that highways with higher traffic volume and speed have a higher acceleration noise and weaving than those with lower volume and speed. In general, vehicles seemed to weave at a slightly higher rate in right-lane than in left-lane closures.

Finally, it is concluded that steady-burn lights are not required when drums with high-intensity reflective sheeting are used as channelizing devices in tangent sections of rural divided highways, including freeways.

It is recommended that the use of steady-burn lights erected on drums that are marked with high-intensity reflective sheeting be discontinued in tangent sections of construction work zones in rural divided highways, including Interstate freeways.

ACKNOWLEDGMENT

The study was funded by the Ohio DOT in cooperation with the Federal Highway Administration. The authors gratefully acknowledge the assistance received from Mohammad Khan and Rodger Dunn of the Ohio DOT in the planning and conduct of the research.

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Publication of this paper sponsored by Committee on Traffic Safety in Maintenance and Construction Operations.