Colored Pavement for Traffic Guidance

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This study was conducted to determine the value of colored pavement material in guiding traffic through intersections. The intersections chosen for study included three geometric types, each with left-turn lanes included as an element of the intersection. These intersections had experienced accident problems related to left-turn maneuvers. The introduction of color was limited to the island area preceding the left-turn area and the left-turn land itself. The island was paved with yellow asphalt and the turning lane with green.

The study consisted of evaluation of vehicle velocity through the intersection, lateral placement of vehicles entering the left-turn lane, and channelizing effect of through vehicles. A before-and-after procedure was used to analyze the effectiveness of color. The results of these analyses indicate that the application of color is effective in channelizing left-turn vehicles entering the left-turn lane. This is accomplished primarily by directing the vehicles past the approach island rather than by inducing the driver to enter the lane earlier. Coloring the pavement did not significantly change the velocity patterns through the intersection. Also, the effectiveness of the colored pavement is lost at night. In fact, the color is barely visible under the light from vehicles.

•THE trend toward increased speeds and the growing complexity of the highway network have created new problems for the driver. The driver, in his role as decision-maker, must assimilate and process information much more rapidly than before. Several research studies (1, 2, 3) are being conducted in an attempt to define the driver's decision-making capabilities as a function of time and information input rate. The results of these studies will provide additional insight into the need for improved means of communication at specified locations along the highway.

There is a need for concurrent research in the field of driver acceptance and recognition of communication aids. Thus, the identification of the need for increased communication can be supplemented with the knowledge of possible means of supply. The most common means of information transfer to the driver is through signs, signals, and pavement marking. The science of communication through these media has made great advances.

For example, studies have resulted in the recognition of the value of standardization as an aid in decision-making. This recognition eventually resulted in a requirement for such standards. Distribution of federal grants for highway construction will be contingent upon the respective states showing substantial conformance with the Manual of Uniform Traffic Control Devices (4) by December 1968. To this end, part of the HPS money in each state has been set aside for inventory and upgrading of signs and markings.

Standards of size, shape, color, and legend have been established for traffic signs throughout the country. These standards, as well as standards for the use of signals and pavement markings, have been published in the Manual. The need for standardization should not be ignored. As vehicle speeds increase, any time reduction in the

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decision-making process will result in increased safety. However, in this period of dynamic industrial and professional growth, some avenue for testing new ideas and products must remain open. The results of such tests can be used to periodically update our standards.

One of the basic elements of the standardization of traffic control devices is color. Certain colors have been adopted as having a specified meaning in traffic control. Red, green, and yellow are probably the best examples.

The National Joint Committee on Uniform Traffic Control Devices has named a special subcommittee on color to expand the list of colors and meanings to convey additional information to the driver. It appears that there are some 14 colors that are easily discernible and could be used in a standardized color-coding scheme (5). Research involving the application of these colors must be conducted to establish the value of expanding the use of color for information transfer.

Both controlled and noncontrolled experiments have been conducted with colors. Michigan, Washington, Minnesota, and Ohio have conducted studies on the use of colored delineators and edge lines to code the on- and off-ramps of freeway interchanges. A different color is used to distinguish the on-ramps, the off-ramps, and the through lanes. Some cities and states use colored route markers to help the motorist distinguish the proper marker within an array. Crosswalks, especially near schools, have been painted in some cities in an attempt to attract the driver's attention. The purpose of these studies is not to establish meanings for particular colors, but to determine the effect of using color for guidance.

Color contrast is another possible use closely allied to color coding. There are situations where the effectiveness of a device is independent of the particular color used so long as a contrast is provided. An example of this is the use of an asphalt overlay on the shoulder area of a concrete highway. This provides a white-black contrast which enables the driver to discern the pavement edge. In some cases where this color contrast was not provided, it was necessary to return and place painted lines on the berm to provide this distinction.

The use of black center lines and lane lines on concrete pavement in lieu of the standard white line is another example of the application of color contrast. The purpose in this case is to identify the location of the center of the pavement. When additional information such as the existence of a no-passing zone must be conveyed to the driver, the principle of color coding is used. The yellow no-passing line is used with both the black and white lines. While the preparation between color contrast and color coding can be established for some uses, the two are not always mutually exclusive.

The use of color for signs, signals, and pavement markings in an attempt to guide or control traffic is well established. The use of color for delineation or for sections of pavement has not yet progressed to this point. The use of colored sections of pavement as a means of providing direction and guidance to the driver is the subject of this study. At present, the study should be classified as one of color contrast, but care must be taken to avoid conflicts with established color codes.

A survey of the literature on the use of colored pavement materials indicates that the distinction between color coding and color contrast is not being maintained. In Chicago, yellow asphalt was used for median strips, whereas in New York it was used for a deceleration lane. Red asphalt has been used for entrance ramps, exit ramps, and approaches to stop signs at various locations. The primary function of each of these is basically color contrast. However, the diversity of uses will make it difficult to standardize a color code which is meaningful to the driver.

There appear to be two basic approaches to the problem of the extension of color coding. One is to standardize the meaning of various colors and then experiment with these color combinations to find situations in which they are effective. The other is to determine, through research studies, the situations where color contrast is valuable, and thus establish a set of standard colors to achieve this contrast. This project would be classified in the latter category. We have attempted to determine the value of the application of color contrast to a specific problem in traffic flow.

This project was designed to evaluate the use of colored pavement as a control and guidance device through intersections with left-turn slots. This evaluation includes an

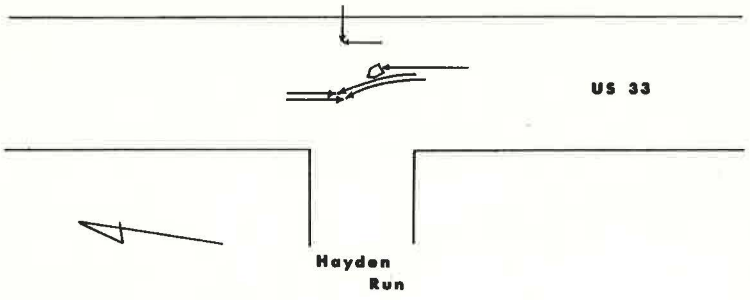


Figure 1. Two-year accident history for US 33 and Hayden Run Road.

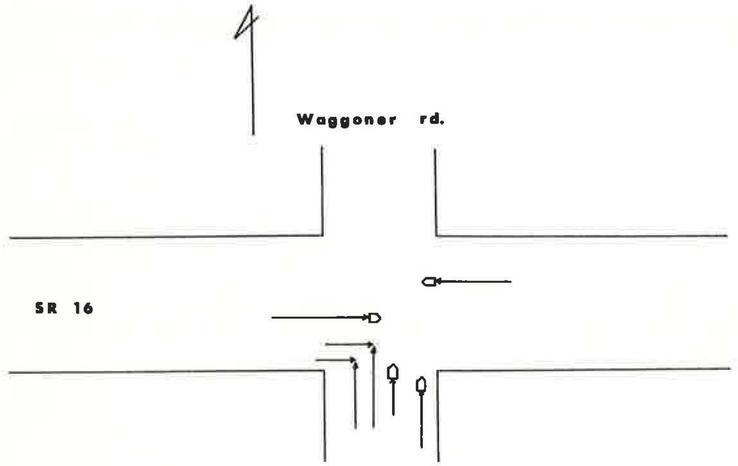


Figure 2. Two-year accident history for SR 16 and Waggoner Road.

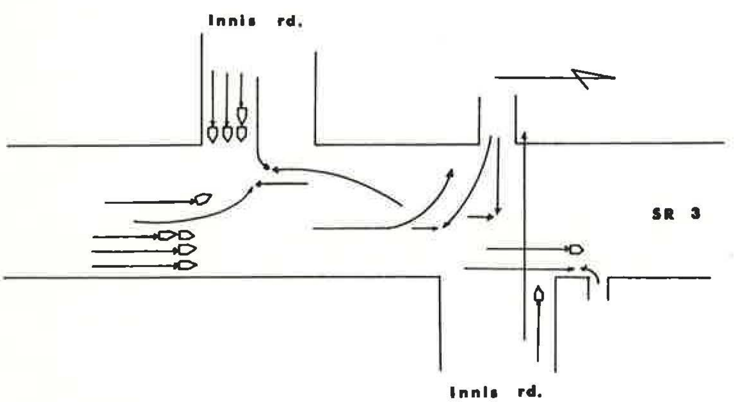


Figure 3. Two-year accident history for SR 3 and Innis Road.

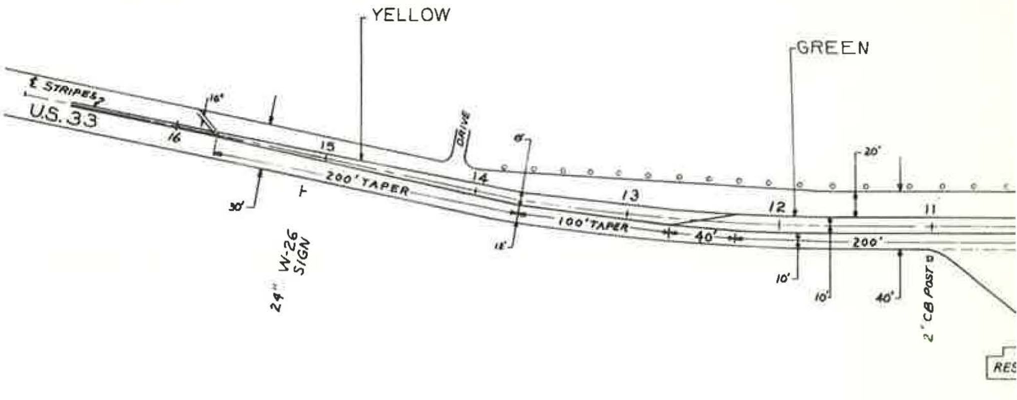


Figure 4. The intersection of US 33 and Hayden Run Road showing details of colored asphalt.

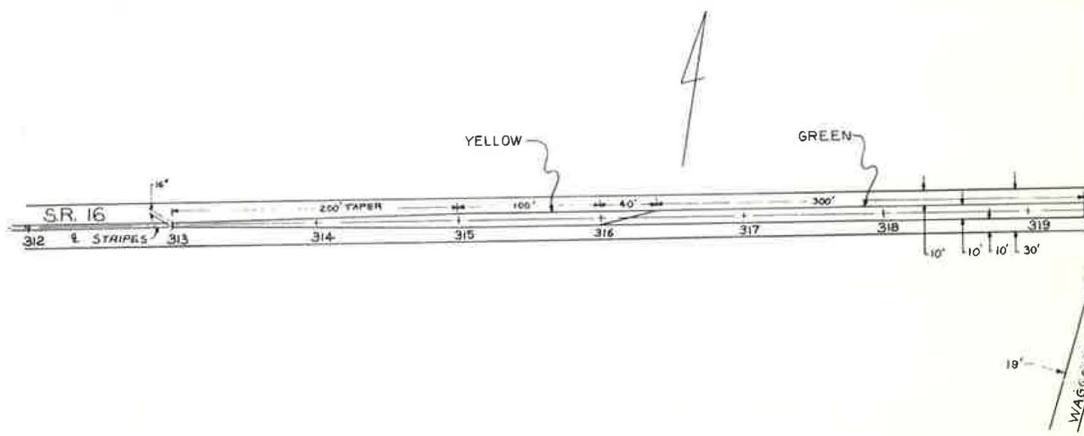


Figure 5. The intersection of SR 16 and Waggoner Road showing details of colored asphalt.

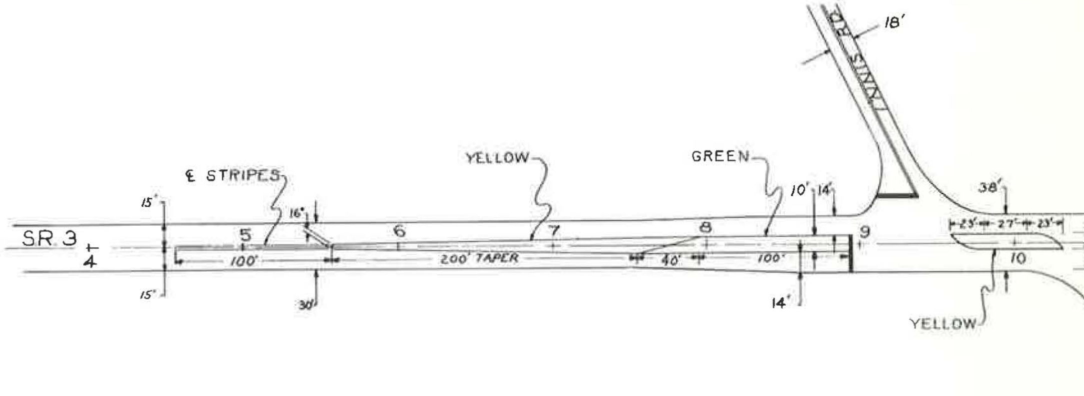
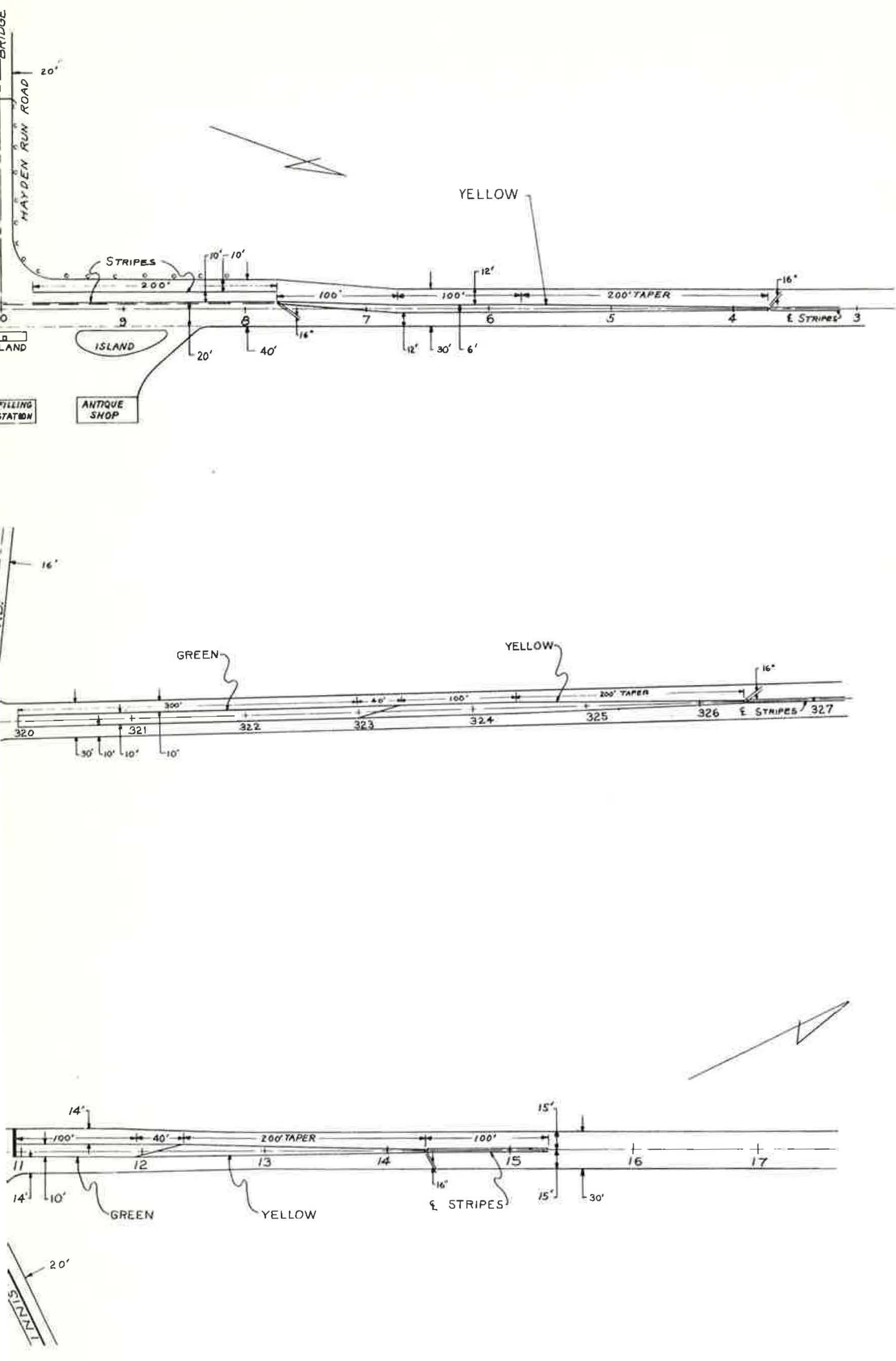


Figure 6. The intersection of SR 3 and Innis Road showing details of colored asphalt.



BRIDGE
HAYDEN RUN ROAD
20'
STRIPES
10' 10'
200'
100'
100'
12'
200' TAPER
16"
YELLOW
℄ STRIPES
16"
ISLAND
20'
40'
12'
30'
6'
ANTIQUE SHOP
FILLING STATION
16'
GREEN
YELLOW
300'
40'
100'
200' TAPER
16"
℄ STRIPES
320
321
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325
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30'
10'
10'
10'
14'
100'
40'
200' TAPER
100'
15'
16"
14'
10'
GREEN
YELLOW
℄ STRIPES
15'
30'
20'
INNIS

analysis of changes in approach speeds, traffic flow patterns, and lane position. The study period established for this project is insufficient to include an analysis of changes in the accident experience. However, accident records will be maintained so that an analysis of this type can be made in the future.

PROCEDURE

The procedure used in this study was based on measurements of traffic flow before and after the installation of color. Comparisons of the data were then made and conclusions drawn from these comparisons.

Selection of Test Sites

The size of the project limited to three the number of intersections that could be paved with colored asphalt. To expedite the project and to include the desired variables within the three sites, intersections with different geometric features were selected.

The intersection of US 33 and Hayden Run Road was one of the sites selected for study. This is a "T" intersection, US 33 being the continuous leg. A copy of the accident history at this location for a period of 24 months preceding the installation is shown in Figure 1. The intersection of SR 16 and Waggoner Road was the second site selected for study. This is a four-leg intersection with a slightly skewed approach. The accident history for this intersection is shown in Figure 2. The third selection was a four-leg intersection with an offset of 80 ft between the two legs of the minor road. This location is the intersection of SR 3 and Innis Road. The accident history for this location is shown in Figure 3.

The design of the left-turn lanes was in accordance with the specifications in the Ohio Manual on Uniform Traffic Control Devices. These designs reflect the differences in approach speeds and turning volumes found at each of the three locations. The intersections are shown in Figures 4, 5, and 6.

Installation

This color was obtained by placing a ½-in. layer of colored asphalt over the existing pavement. Pavebrite II, a two-component synthetic binder plus pigment, was used in this study. The asphalt was placed as a standard maintenance project under the supervision of the Division Maintenance Engineer. The area cross-hatched with white paint in the standard treatment was covered with yellow asphalt, and the left-turn lane was covered with green asphalt.

The color section was based on existing practice within the Ohio Department of Highways, and in concurrence with the recommendations in the "Research Prospectus on Colored Pavements" prepared by the U.S. Bureau of Public Roads. The use of yellow as a barrier of indication of an area of caution has long been a practice. The Research Prospectus states that the color meaning should be:

> Yellow: The color yellow can be used to indicate areas of no trespassing. This would, generally, restrict its use to islands and medians.
>
> Green: The color green can be used to indicate areas of traffic merging and diverging or potential lane changing.

A left-turn lane was considered to be an area of traffic divergence and, thus, within the defined limits for the use of green.

RESULTS

Field Data

The collection of field data was designed to achieve the established objectives as nearly as possible. Vehicle speed, lateral placement, and the flow pattern are treated separately, but it would require the combination of these three to adequately describe the effectiveness of color as a guidance device.

TABLE 1

SPEED DATA FOR THE INTERSECTION OF SR 16 AND WAGGONER ROAD

Distribution	Before	After 1	After 2
(a) Eastbound—650 ft			
Average speed	46	45	49
15%	40	37.5	40
50%	46	44	48
85%	52	51	54
(b) Eastbound—300 ft			
Average speed	45	43	39
15%	33.5	34.5	31
50%	45	40	37
85%	54	46	43
(c) Westbound—650 ft			
Average speed	52	48	51
15%	46	41.5	45
50%	51	47.5	50
85%	53.5	57.5	56
(d) Westbound—300 ft			
Average speed	52	48	47
15%	40	41	38
50%	47.5	47	45
85%	54	54	54

The data on speeds and placement were collected at three different times, and the flow-pattern data twice. The time periods are referred to as "before," "after 1," and "after 2." The "before" data were taken approximately six months prior to the installation of the colored asphalt, the "after 1" data were taken in the first month following the installation, and the "after 2" data were taken six months after the installation.

Speed

Two vehicular spot speed checks were taken at the approach to each left-turn lane. The first check was made at a point approximately 600 ft from the intersection. This point was selected because it was the distance at which the driver could first see the island. The second speed check was taken at the point where the driver could first see the left-turn lane. This distance was approximately 250 ft from the intersection for the selected study sites. In all cases, this point was adjacent to the island. The factor of interest in the speed measurements was the initial effect on the driver. For this reason the speed distribution as well as the mean speed was used in the analysis.

The spot speeds were taken with a radar meter concealed in a mailbox. A 100-ft cord is used in conjunction with the mailbox so that the recorder can be concealed some distance from the meter. This arrangement was used to avoid the influence of the observer on the speed pattern. An analysis of the speed checks taken immediately after the application of the colored asphalt indicated generally lower speeds. In most cases the speed reductions were quite small and well within the variance normally associated with speed checks had there been no changes made.

Tables 1 and 2 give the values of four parameters of the speed distribution before and after the installation of the colored asphalt. Speed checks were not taken at the intersection of SR 3 and Innis Road because this is a signalized intersection. The columns titled "After 1" refer to data taken immediately following the installation, and the "After 2" columns refer to data taken six months later.

The 15 and 85 percentile points were chosen to determine whether the use of color affected the speed distribution. There are no significant speed differentials in any of the parameters recorded. Likewise, there are no apparent trends in the speed profiles when compared by location in respect to the intersection. The mean speed is lower at the location nearest the center of the intersection, but this is also true of the other parameters of the speed profile. The eccentricity or skewness of the distribution appears to be a property of the location and is not affected by the addition of color to the pavement.

The results of this speed study tend to dispel one possible criticism of the use of colored

TABLE 2

SPEED DATA FOR THE INTERSECTION OF US 33 AND HAYDEN RUN ROAD

Distribution	Before	After 1	After 2
(a) Northbound—600 ft			
Average speed	51	45	46
15%	43.5	37.5	40
50%	50	44	47
85%	57	49.5	54
(b) Northbound—250 ft			
Average speed	45	45	43
15%	36.5	37	35
50%	45	43	40
85%	52.5	49	49
(c) Southbound—600 ft			
Average speed	46.04	44	44
15%	38.5	37	37
50%	43.5	42.5	43
85%	51.5	49.5	48
(d) Southbound—250 ft			
Average speed	42	43	42
15%	34.5	36.5	34
50%	42	41	40
85%	47.5	48	48

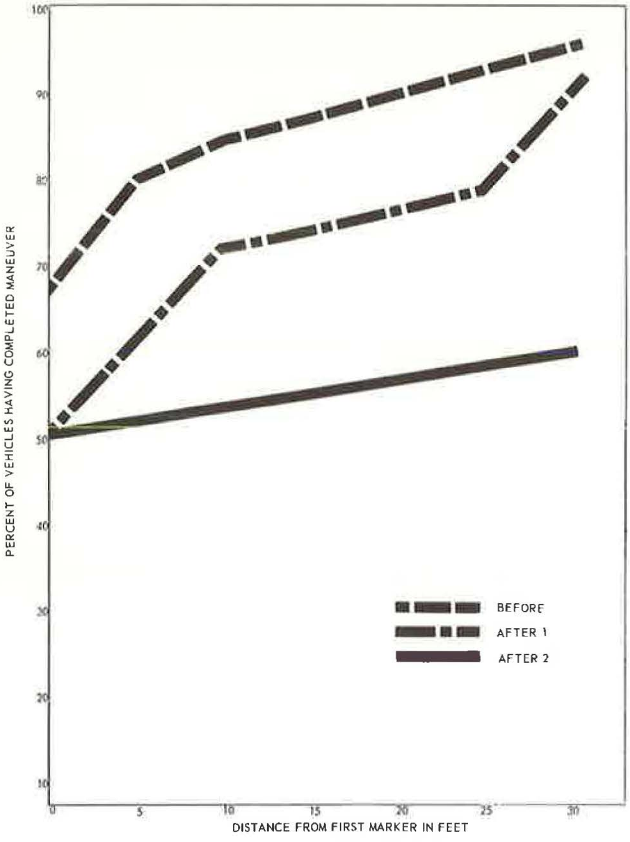

Figure 7. The percentage of left-turn vehicles clearing the through lane at selected locations—eastbound traffic at SR 16 and Waggoner Road.

pavement. The application of color does not cause the driver to decrease his speed when traversing the intersection. This is particularly significant in that the normally cautious driver, as determined by the 15 percentile point on the speed distribution, is not affected.

The conclusion drawn from this part of the study was that the application of color did not adversely affect the drivers continuing through the intersection on the main line.

Lateral Placement

Vehicle placement was the measure selected to determine the effectiveness of the colored pavement as a method of guiding left-turning vehicles into the proper channel. The vehicles were recorded at selected locations along the left-turn lane as either encroaching on the through lane or clear of the through lane. The effectiveness of the color was determined by the difference in the percentage of vehicles encroaching on the through lane at the selected locations.

The lateral placement measurements were taken to determine the distance from the beginning of the left-turn lane to the point at which the turning vehicle completely cleared the through lane. The lateral measurement was recorded as positive or negative, depending on whether the through lane was cleared, at selected distances from the beginning of the left-turn lane.

The outside edge of the left-turn lane was marked at 5-ft intervals, starting at the location marked on Figures 1 through 3, and moving picture films were taken of vehicles entering the lane. This picture was analyzed with the aid of an analyst projector to determine the lateral position of the vehicles at each of the marked locations. The percentage of the vehicles that had completed the maneuver (and thus freed the through lane) was recorded at each location. The percentages were used in the analysis of the effect of the colored pavement on traffic operations.

Figure 7 is a graph of the data for the eastbound approach to the intersection of SR 16 and Waggoner Road. The pattern of entry is substantially different in the "before" and "after" periods. Without the colored asphalt, a greater percentage of the vehicles enter the left-turn lane early. In fact, 66 percent of the left-turning vehicles completely cleared the through lane before reaching the first marker. This percentage dropped to 50 percent when the measurements were taken after the installation of the colored asphalt. In the "After 2" data, the percentage remained constant, but the slope of the line changed. In fact, only 10 percent of the vehicles entered between the beginning point and the 30-ft mark. The percentage of vehicles still encroaching on the through lane is consistently higher for the "after" situation at all measured points.

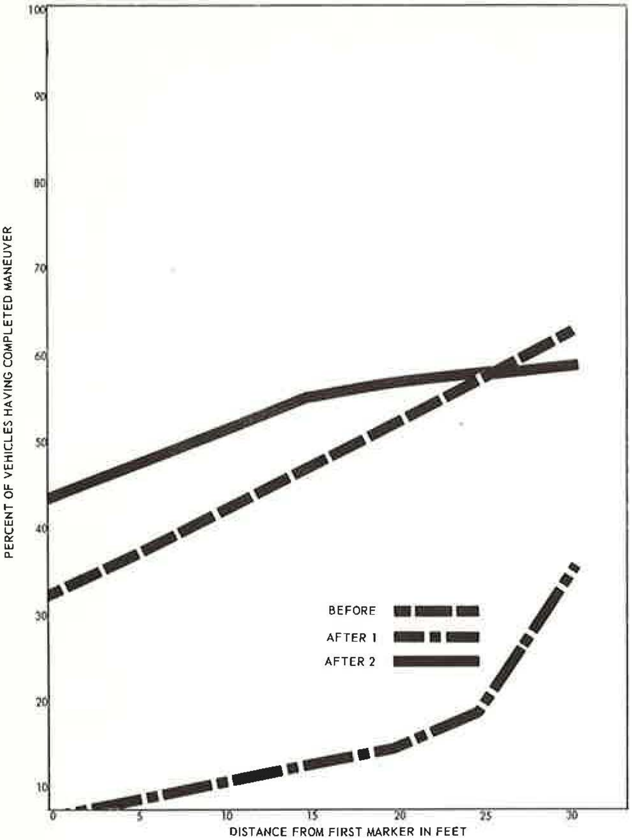

Figure 8. The percentage of left-turn vehicles clearing the through lane at selected locations—westbound traffic at SR 16 and Waggoner Road.

The westbound approach to this same intersection exhibited an entirely different pattern of entry into the left-turn lane. On this approach, 31 percent of the vehicles cleared the through lane before reaching the first marker in the "before" period, and only 6 percent in the "After 1" period. In fact, only 34 percent of the vehicles in the "After 1" period had cleared the through lane within 30 ft. In contrast, 63 percent of the vehicles had cleared the through lane in the "before" period. These data are shown in Figure 8.

In the "After 2" period, the pattern of entering vehicles reverted back to the original. For this time period, 44 percent of the vehicles had entered the left-turn lane prior to the first marker and 58 percent had completed the maneuver within 30 ft. It was apparent that the introduction of color had the immediate effect of discouraging drivers from entering the lane, but with time this hesitancy subsided.

The effect of the colored asphalt was more consistent on the two approaches to the SR 3 and Innis Road intersection. Most of the left-turning vehicles from both directions entered the turning lane within the first few feet. The percentage of vehicles which had completely cleared the through lane before the first marking was 80 percent for the northbound direction and 84 percent for the southbound direction. After the colored asphalt was installed, these figures dropped to 61 percent and 56 percent respectively. Figures 9 and 10 were prepared from these data.

The "After 2" data follow the "After 1" data remarkably well. There seems to be little immediate effect of the color which is not retained through at least a six-month period. If there is any difference at all, it is an amplification of the changes that occurred immediately after the colored asphalt was placed. This is in direct opposition to the behavior observed at the first location.

The influence of the signal and the lower speeds at this intersection probably contributed to the large number of vehicles entering the left-turn lane within the first sections. However, it was observed that many of these vehicles were violating the painted island areas and were driving across the island area in their approach to the intersection. This practice was reduced when the colored asphalt was placed. This change accounted for the difference in the "before" and "after" period at the intersection.

Results from the third study site, US 33 and Hayden Run Road, are shown in Figure 11. This is a "T" intersection, so there is only one left-turn lane at this site. The pattern of entry into the left-turn lane is similar to that found at SR 3 and Innis Road. Before the colored asphalt was added, 95 percent of the vehicles entered the left-turn lane before passing the first marker. Many of these vehicles were driving over the painted island to accomplish this.

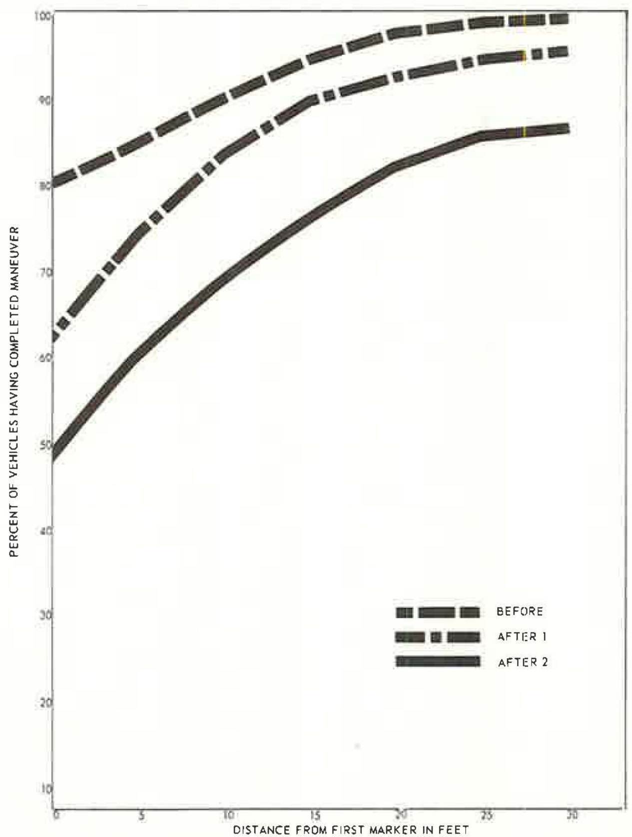

Figure 9. The percentage of left-turn vehicles clearing the through lane at selected locations—northbound traffic at SR 3 and Innis Road.

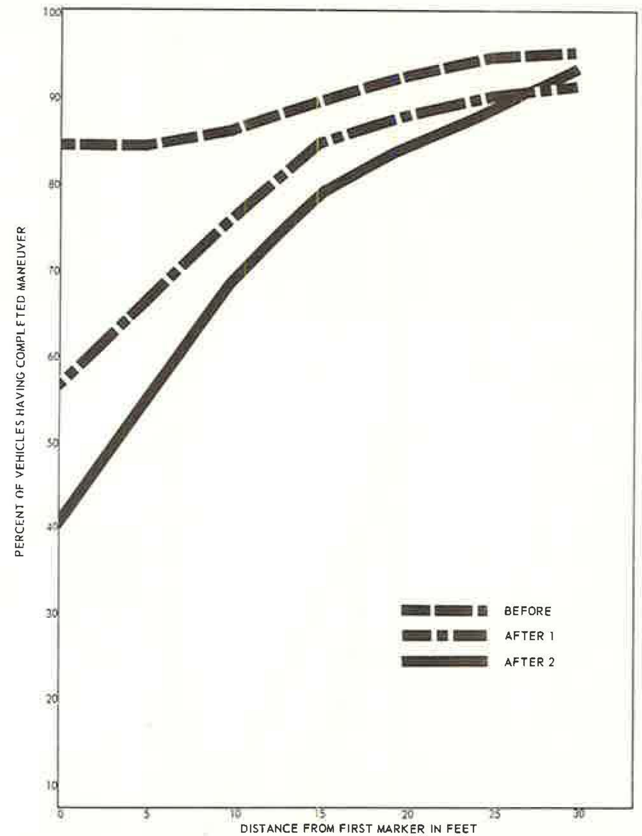

Figure 10. The percentage of left-turn vehicles clearing the through lane at selected locations—southbound traffic at SR 3 and Innis Road.

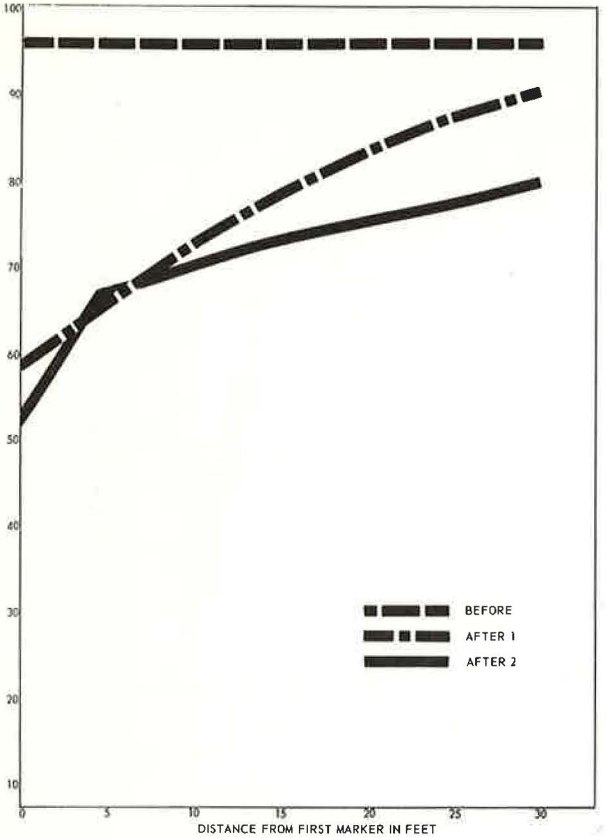

Figure 11. The percentage of left-turn vehicles clearing the through lane at selected locations—northbound traffic at SR 33 and Hayden Run Road.

The curve showing the percentage of vehicles that have cleared the through lane in the "after" period is similar to that found at the other locations. Over 58 percent of the vehicles enter the left-turn lane before the first marker, and 90 percent have entered within the first 30 ft. These percentages change to 52 percent and 90 percent in the "After 2" data. Once again, the tendency is to amplify the original difference.

Traffic Flow Patterns

The preceding two measures provided quantitative data on the effectiveness of adding color to the pavement. The third measure selected is difficult to describe in quantitative terms, and it is illustrated as a qualitative measure of the effectiveness of color.

Time exposures of vehicles making left turns at the subject intersections were taken at night from an elevated position. The camera was operated from the top of a platform lift truck at an elevation of about 18 ft. A total of 15 vehicles was recorded on each picture, and the uniformity of the flow pattern was compared for the "before" and "after" period. While this type of measure is not very definitive, it provides a useful comparison when considered in conjunction with the previous two measures.

The results of the third parameter selected for study are strictly qualitative. No attempt was made to quantify the flow patterns on the "before" and "after" photographs. Visual inspection of the sets of photographic pictures indicates that the flow patterns created by the taillights of vehicles entering the left-turn lane after the colored asphalt was in place is more uniform than that exhibited before the installation.

However, this difference does not appear as significant as that found in the lateral placement study. The reason for this probably lies in the non-reflective property of the colored asphalt. It is very difficult to discern the colored asphalt from the through lane at night. In fact, the painted island area has a considerably greater visibility at night than the colored asphalt.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions reached in this study can be summarized as follows:

1. The introduction of colored asphalt at an intersection does not significantly affect the velocity of vehicles in the through lane.
2. During the day, vehicles exhibit a more uniform pattern of lane changing with colored asphalt than with the painted island.
3. The colored asphalt has little effect on traffic flow patterns at night.

The lateral placement data collected at all five of the left-turn lanes are plotted on the same graph for comparative purposes. The wide differences among the patterns

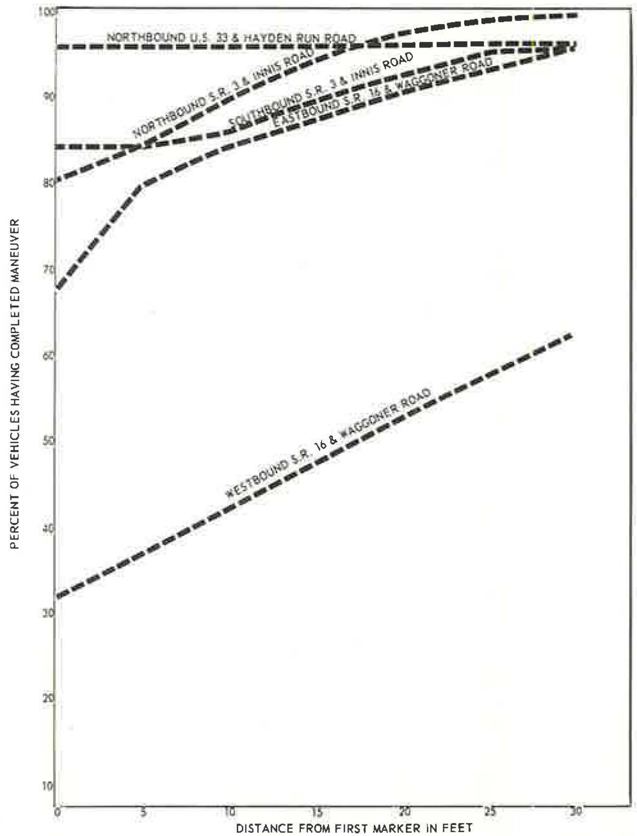

Figure 12. The percentage of left-turn vehicles clearing the through lane at selected locations—"before," all sites.

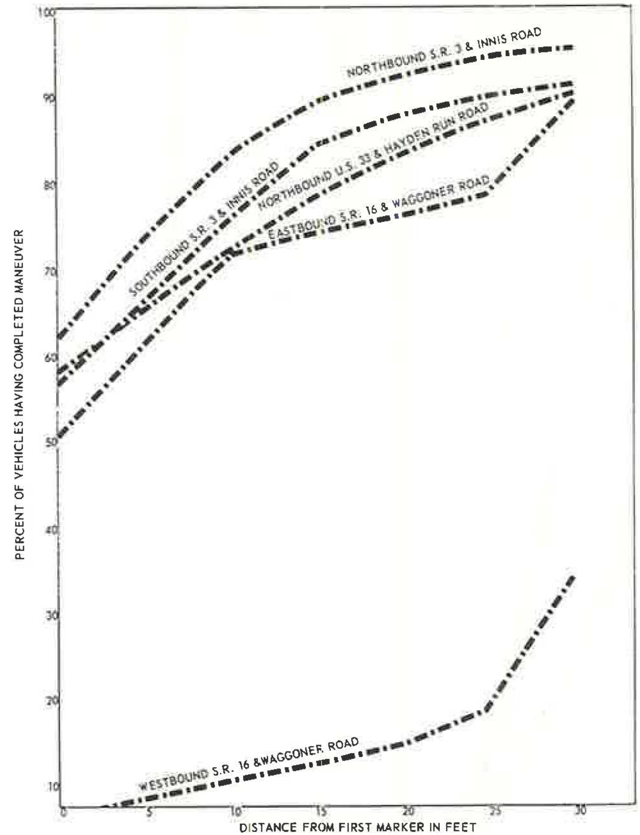

Figure 13. The percentage of left-turn vehicles clearing the through lane at selected locations—"after 1," all sites.

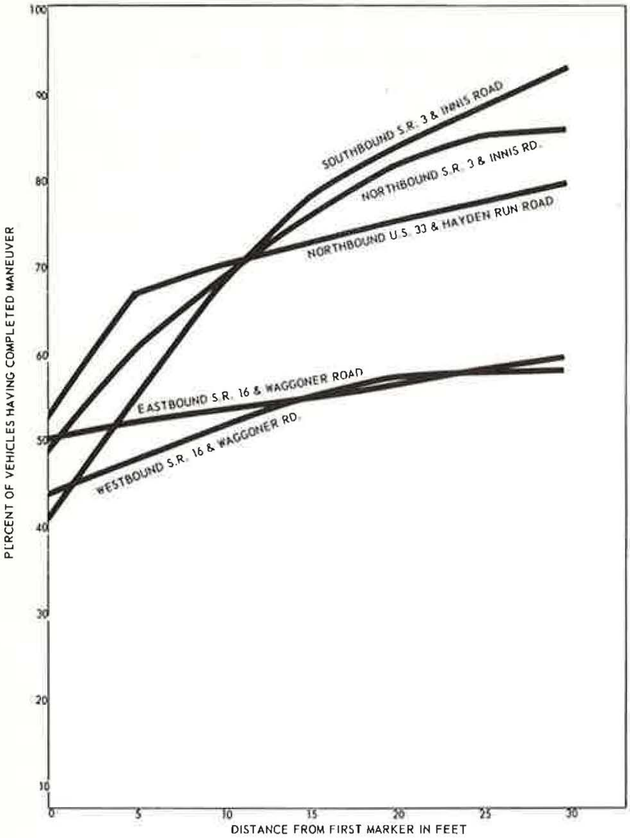

Figure 14. The percentage of left-turn vehicles clearing the through lane at selected locations—"After 2," all sites.

exhibited at the various locations before the installation of the colored asphalt are shown in Figure 12. With the exception of one approach, the patterns exhibited after the colored asphalt was placed are fairly consistent. These data are shown in Figures 13 and 14.

Based on these data, it appears that the application of the colored asphalt is effective in channelizing the left-turning vehicles entering the turning lane. This is accomplished primarily by directing the vehicles around the island area rather than by inducing the drivers to enter the left-turn lane earlier. In fact, the percent of vehicles completing their maneuver at selected distances is consistently higher for the "before" case than the "after" case.

One interpretation of this change in the pattern is that the yellow asphalt directs vehicles around the island area better than the painted cross-hatching, but that the use of a green left-turn lane is not significant in directing the turning vehicles into the proper lane.

Recommendations

Based on the results of the data collected in this study, the recommendation for use of colored pavement would be limited to one problem area. The problem, as defined by accident history or engineering judgment, must involve vehicles moving in opposite directions. The most pronounced effect of the colored pavement was to discourage vehicles from crossing the channelizing island when entering a left-turn lane.

The use of the green pavement in the turning lane apparently did not affect the drivers' patterns of entry into the lane. If this use had been effective, a steeper slope of the lines shown in Figures 13 and 14 would be expected. The slope of these lines, however, was nearly the same as the "before" case shown in Figure 12.

This study and the other studies reported on the use of colored pavements provide evidence that the use of color in pavements may well be an effective traffic control device. It appears that this effectiveness will be more pronounced when used to indicate areas of "no trespassing" rather than to indicate paths or corridors to be followed.

The limited scope of the project was not sufficient to provide data upon which generalized conclusions can be stated with certainty, but it does provide a starting point. Further research into possible uses of colored pavement is warranted by the results obtained in this study. In Ohio, we propose to conduct additional experiments on possible uses.

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