The Efficacy of Orange Lane Delineations in Highway Work Zones

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With over 100,000 crashes in the work zone per year, it is essential that we as builders discover and implement innovative solutions to maximize field crew and public safety in high traffic areas. A recent trend in the Heavy Civil Construction industry has been the implementation of temporary fluorescent orange striping in active highway work zones. When traditional white or yellow lane markings are removed, a faint residue is left behind and as construction crews repeatedly shift lanes, multiple overlapping removal scars begin to create confusion for drivers that leads to an increased risk of crashes. To eliminate this confusion as well as to reduce traffic speeds and increase awareness in the work zone, the Wisconsin Department of Transportation, the North Texas Tollway Authority, and the Kentucky Transportation Cabinet have conducted successful experimentations with orange lane delineations. The most recent experimentation trial is currently being conducted by Caltrans District 11 and is expected to conclude in late 2022. The objective of this research is to measure the overall success rate of orange striping and to determine common obstacles faced during the installation, exposure, and removal of orange striping.

Key Words: Traffic Safety, Heavy Civil Construction, Lane Delineation, Road Markings, Work Zone Safety

Background

Modern asphalt roads have been a staple in American transportation since the early 1870's and over the past 150 years, countless innovations have cumulated to create the highly complex highway infrastructure we see today. In 1911 Edward N. Hines, chairman of the Wayne County Board of Roads, was inspired to lay the first road centerline after witnessing a leaky milk wagon drive down a road in Michigan (ICStriping, 2015). It wasn't until 1917 that these white centerlines began gaining traction across the United States, and by 1954 the use of white medians became a mandatory standard. After the manual on Uniform Traffic Control Devices was published, median stripes were repainted yellow to better coordinate with existing traffic warning signs and white stripes were dedicated to divide traffic flowing in the same direction across all 50 states (ICStriping, 2015). Once a uniform road system had been established, the focus had shifted from nationwide uniformity to overall public safety.

In the early 1950's, Caltrans chemist Elbert Botts invented raised pavement markers, or "Botts Dots", that served to alert drivers who have drifted out of their designated lane as they create a vibration when driven over (Kerr, 1985). By the early 2000s, over 25 million Botts Dots had been installed throughout the California highway system in varying shapes and sizes. In recent years, however, Botts Dots have lost popularity as they are often not reflective and cannot be recognized by "lane keep" features on smart cars that utilize lane stripes to center the vehicle. In the 1950's drivers also began to see Rumble Strips on roads that are essentially divots in asphalt that, similarly to Botts Dots, create a vibration when driven over to warn drivers who have veered too close to the shoulder of a road or highway.

In addition to providing physical signals such as signage, Botts Dots, and Rumble Strips to help manage traffic, the US Department of Transportation (DOT) has recently decided to provide drivers with color designations as well. Between 2010 and 2015, DOT has implemented green segments of the road dedicated to bike lanes, red segments for bus lanes and zones, and purple segments to FasTrak and Toll Roads (SEH, 2017) – images of these color designations can be seen below in Figure 1. Orange along roads has been designated to represent safety features and construction activities as it is easily visible under all conditions and is already heavily associated with the construction industry – the shade "Blaze Orange", also referred to as "Safety Orange", is a high-visibility color recognized by both the Manual for Uniform Traffic Control Devices (MUTCD) and the Occupational Safety and Health Administration (OSHA) (Mall, 2022).

Figure 1: Color designations of bike lanes, bus lanes, toll roads, and highway work zones.

Introduction

Despite doubled traffic violation fines, 24-hour "Slow for the Cone" zones, and ample signage, drivers continue to disregard safety precautions when passing through the work zone. In a 2021 survey conducted by the Associated General Contractors of America, 60% of highway builders have reported between one and five work zone crashes resulting in serious injuries and schedule delays (AGC, 2021). Additionally, 78% of builders have reported that the risk of crashes in active construction zones is much more significant now compared to risk in the previous decade (AGC, 2021). With increasing levels of risk in the industry, significant efforts are being made to maximize safety in highway construction. The utilization of temporary fluorescent orange striping is the newest safety trend seen along highways and roads. The goal is to signal to drivers that they are entering an active construction zone in attempts to increase and maintain driver awareness, therefore reducing the potential for accidents, injuries, and fatalities. This traffic delineation method is fresh to the industry and has been tested in Wisconsin, Texas and Kentucky and is currently in the trial phase in California under the guidance of Caltrans along the North Coast Corridor of the I-5 freeway in San Diego.

Literature Review

Wisconsin Department of Transportation

WisDOT decided to experiment with temporary lane delineation to help drivers navigate winter roads in the presence of snow, ice, and salt which make it difficult to identify and maintain in a white striped lane. The 18-month experiment included the usage of orange striping during the construction of the Zoo Interchange project (I-94, I-894 and I-41) along 10 miles of an interchange exposed to over 350,000 vehicles per day (Hadley & Patrick, 2020). All edge and skip lines were striped with variations of orange paint, epoxy, and tape to gain insight on which installation method was the most efficient and effective – this project required hundreds of marking applications and removals throughout the course of construction (Hadley & Patrick, 2020).

In addition to frequent changes in lane configurations, WisDOT reported the following challenges: added time and costs to clean orange out of white/yellow paint striping trucks, color fading, difficulties maintaining reflective bead retention, and complicated evaluations of success. The team recommends that future experiments should utilize water-based paint accompanied by raised pavement markers rather than epoxy paint in warmer climates due to its high resistance to UV exposure and increased visibility in wet conditions (Hadley & Patrick, 2020). Quantitative research showed that collision rates in this experiment remained constant with those observed in the control region (I-94), however public survey results showed successes in increased awareness of the work zone and lane visibility (Shaw, et al., 2018).

North Texas Tollway Authority

North Texas Tollway experiments began along the Sam Rayburn Tollway in August of 2019 and consisted of 4” continuous profile thermoplastic delineations with bumps positioned every 18” (Hadley & Patrick, 2020). The goals for this experiment were to encourage drivers to maintain in their designated lanes and to increase overall site safety. NTTA worked alongside the Texas A&M transportation Institute to collect, analyze, and report data gathered throughout the trial. This data includes vehicle lateral positioning (edge/lane hits obtained from CCTV footage), retro reflectivity, color values, and public opinion surveys. Retro reflectivity data for both the orange and white striping had decreased, and color values faded over time and exposure as expected.

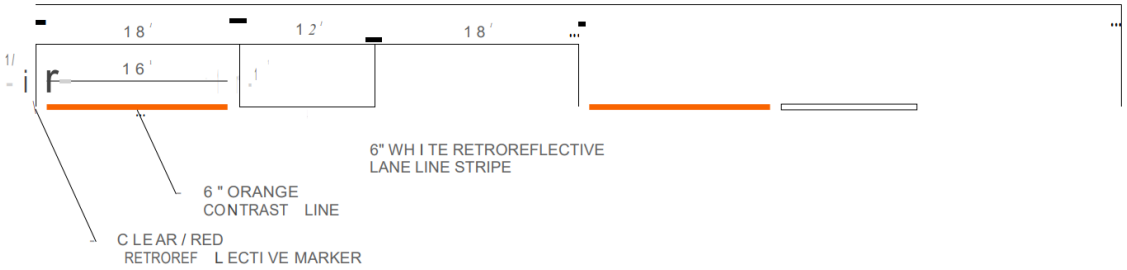
Kentucky Transportation Authority

In October of 2019, the Kentucky Transportation Authority began installing temporary orange striping featuring wet-reflective elements along the I-75 expansion in Laurel County. The work zone included one orange zone, two control zones, and two non-work zones ranging between 4.3 and 7.3 miles (Staats, Agent, & Lammers, 2021). The team decided to minimize the lengths of each zone to ensure that drivers would not become accustomed to the orange striping over long distances, causing the delineation to lose its intended effect of maintaining awareness. KYTC combined the orange striping with 8’ tall painted speed limit markings to further encourage drivers to adhere to the 55mph work zone (Hadley & Patrick, 2020). The success of this experiment was measured by retro reflectivity, speed differentials, crash reports, and public perception.

Caltrans – North Coast Corridor

The most recent orange lane delineation trial is currently being executed by Caltrans district 11 along the I-5 freeway in San Diego, California. To determine success of the experiment, CCTV footage will be used to monitor motorist behavior when exposed to white and orange striping and California Highway Patrol will be consulted for collision occurrences and speed differentials. Details of the two primary design alternatives being utilized are shown below in Figure 2:

Alternative 1 (Southbound): 16’ long 6” wide contrasting lines preceding a 6” white line



Alternative 2 (Northbound): 2” wide contrast stripes along both sides of the 6” white line

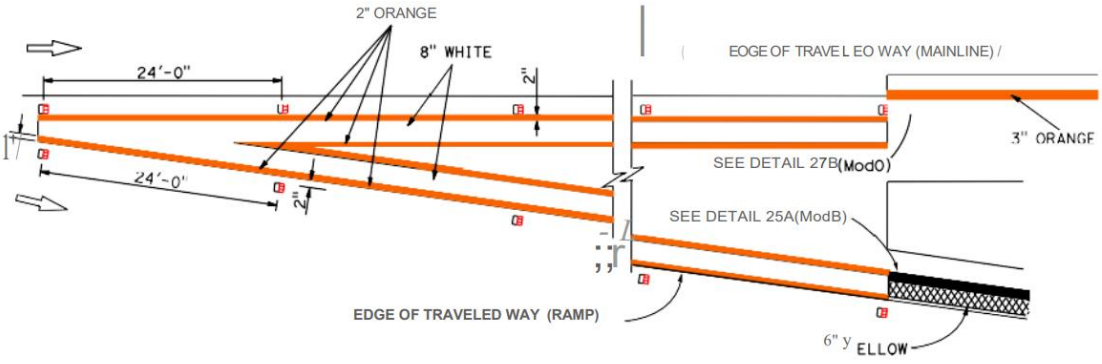


Figure 2: Caltrans design alternatives for orange delineation placement

The experiment is expected to conclude late 2022 so final conclusions and overall success have yet to be determined, however lessons learned thus far include the following:

- Initial mobilizations utilized fluorescent orange tape combined with bead elements, however all tape has been replaced with orange striping as it has failed to meet expectations
    - Tape had bleached to peach after UV exposure and approximately 30% of the tape was lost after heavy rain
    - Due to weather conditions, any coastal location will likely not be conducive for the usage of tape or paint
- Difficulties with 30 mil bead retention, 15 mil may have been closer to doable however this was not executed because it would require trucks to be specially set up for this installation
- Lack of specifications have led to heavy reliance on manufacturer recommendations

Methodology

To gain insight and data not discovered in the literature review, a brief seven question survey was created and sent out to individuals from each of the relevant departments of transportation. The survey was intended to reach a large population of individuals including field engineers, project engineers, superintendents, foremen, etc., however due to a limited time frame and lack of responsiveness from DOT representatives, this was not possible. When conducting research on Government funded trials, such as orange delineation, it is important to note that this niche of study requires extensive time, cooperation, and communication to complete. Responses and opinions obtained were supplied solely by P.E.'s from WisDOT and KTC.

Survey Questions

1. What combinations of paint/epoxy thickness and bead types were used?

2. What major challenges/obstacles were encountered throughout the experiment?

3. Did you experience budget increases/decreases?

4. Did data acquired show an increase in safety due to the installation of orange striping?

5. What would you recommend to departments looking to experiment with orange lane delineation?

6. Do you see orange striping becoming an industry standard in the coming years? Why or why not?

7. Please provide any additional comments (personal opinions, public opinions, etc.)

Survey Analysis

Wisconsin Department of Transportation

Freeway Oversight Engineer: WisDOT utilized both retro-reflective and standard beads imbedded in fluorescent orange epoxy paint of a standard thickness. Experiments were conducted with water-based paint in the Summer and raised pavement markers were used in non-Winter months to enhance visibility in wet weather and at night. Orange tape was also installed in short lengths but failed as they faded more significantly than striping over time. Major obstacles faced included increased costs to clean paint trucks and difficulties maintaining color values due to exposure to UV light. An unexpected response to the survey indicated that color blind drivers had a harder time distinguishing the markings from the adjacent asphalt. These challenges were also present in the Kentucky and Texas trials and will require further experimentation from departments of transportation to overcome. WisDOT would recommend the use of orange lane delineations in complicated work zones, or in simple work zones (zones with straight staging of striping) to indicate lane shifts and/or lane crossovers.
The interviewee shared that they believe orange striping will become industry standard in the coming years for the following reasons:

- Public survey results reported that between 75% - 80% of drivers preferred orange markings over the traditional white or yellow.

- Accident reports obtained before and after installation showed that the number of accidents remained the same. While this may not appear to be an indicator of success, it was determined that safety was improved since more accidents are expected to occur as work zones become increasingly complicated to navigate.

- Local law enforcement officers were supportive of the orange markings as they appeared to be an effective highway safety precaution.

- Orange striping has been successful in maintaining driver awareness in the work zone and studies are currently being conducted on the success of orange markings conveying the presence of construction zones to autonomous vehicles.

Kentucky Transportation Cabinet

Chief District Engineer: KTC utilized orange striping along a six-lane widening project in Laurel County - this stretch of the I-75 had a high potential for numerous crashes due to high traffic volumes and extensive construction. The primary goal was to reduce crashes in the work zone, lower rates of secondary crashes, and reduce resulting traffic congestion and delays by increasing work zone awareness, tracking lane shifts, and lowering speed differentials throughout the entirety of the construction zone. This experiment utilized all weather orange striping supplemented with temporary pavement markers at transition points along the highway. Orange markings and delineators were not used along ramp lines or gore areas of Exit 29 in efforts reduce driver confusion when entering and exiting the I-75.

The interviewee expressed that they feel as though "the orange paint is a good concept to delineate the start and entire length of a work zone but needs a lot more research behind it before it can be successfully implemented" for the following reasons:

- The main issue KTC encountered lied with maintaining retro reflectivity of the orange paint, which has not had enough time or trials to determine successful methods to reach requirements

- Construction crews were unable to pass reflectivity tests despite multiple attempts.

- Public opinion surveys produced several complaints regarding difficulties seeing the orange paint at night and in wet weather

- A complaint was submitted by a color-blind individual who, like in the Wisconsin trial, had difficulty distinguishing the orange stripes from the surrounding asphalt.

The orange delineation trial conducted in Kentucky had little effect on work zone speeds and crash prevention. Regarding speed differentials, KTC deduced that "drivers may reduce their caution and increase speed in the work zone as they become complacent and familiar with the work zone" (Staats, Agent, & Lammers, 2021). While crashes in clear weather increased by about 18% after installation of orange striping, crashes in rainy, cloudy, and snowy conditions were successfully reduced.

Speed comparison and crash result data referenced above is shown below in Figures 3 & 4:

Zone	Direction	RT unique	BMP	EMP	Daytime Average Speed	Nighttime Average Speed
Orange	Cardinal	063-I -0075 -000	28.9	33.2	66.65	66.50
Orange	Non-Cardinal	063-I -0075 -010	28.9	33.2	64.38	64.60
Control WZ1	Cardinal	063-I -0075 -000	40.7	48	66.89	66.60
Control WZ1	Non-Cardinal	063-I -0075 -010	40.7	48	65.03	64.50
Control WZ2	Cardinal	102-I -0075 -000	55.7	64.5	67.95	67.03
Control WZ2	Non-Cardinal	102-I -0075 -010	55.7	64.5	67.23	66.21

	Orange Before	Orange After	WZ1 After	WZ2 After
Clear	49.0%	66.7%	54.8%	27.7%
Raining	24.5%	8.3%	21.0%	61.5%
Cloudy	24.5%	21.7%	22.6%	9.2%
Snowing	2.0%	1.7%	0.0%	1.5%
Severe Crosswinds	0.0%	1.7%	0.0%	0.0%
Fog With Rain	0.0%	0.0%	1.6%	0.0%

WZ1 – Control Work Zone #1 WZ2 – Control Work Zone #2

Figure 3: Comparison of speeds throughout several zones in the I-75 corridor.
Figure 4: Crash summary based on weather conditions.

Conclusions

With only four trials conducted in the United States, it is evident that temporary orange lane delineation as a concept does not have adequate research behind it to ensure its success as an effective highway safety measure. However, this is not to say that experiments have been unsuccessful – trials conducted have reached the overall goals of increasing driver awareness and reducing crashes in the work zone. For orange striping to become an industry standard in the heavy civil construction industry, the following factors must be considered:

- Common/State-wide specifications need to be developed to obtain uniformity
- Solutions to increase visibility of the orange striping for color blind individuals
- Time and cost favorable methods to clean orange out of white/yellow striping trucks ***or***
- The development of striping trucks for orange paint/epoxy
- The development of water-proof orange lane tape
- Methods of resistance to UV exposure to reduce fading/bleaching overtime
- Methods of bead retention
- Adjustments to ensure striping meets retro-reflectivity requirements
- Success rates of autonomous vehicles registering orange striping as an indication of a work zone

Reflections and Future Research

The initial intent of this research was to perform a case study on the successes and challenges encountered by Caltrans throughout the installation, duration, and removal of orange lane delineation along the North Coast Corridor. The plan to determine the results of the experiment was to review CCTV footage, speed differentials, and public opinion forums monthly, however it was determined that Caltrans would not release this data periodically but rather in a single conclusive document upon completion at the end of this year. Through correspondence with Project Engineers on site, some periodic data was attained however it was not a substantial amount that could have been used to complete this research. This led to a change in the proposal from a case study on Caltrans alone to exploratory research on all transportation departments that have completed successful temporary orange striping experiments within the United States. Despite reaching out to each respective transportation department as well as 14 individuals who had participated in these trials alongside phone calls and multiple follow-up emails, only three survey responses were obtained.

In future research conducted on this topic, a larger sample of industry experts should be used to obtain more accurate conclusions and determinations of success. This sample may include manufacturers of bead types and paint, striping service providers, field engineers, project engineers, superintendents, foremen, laborers, and project managers. While this research was broad in topics covered, it may be wise to select a narrow topic within temporary orange lane delineation such as safety or installation methods to ensure that accurate conclusions can be drawn within a limited time frame. Selecting a subtopic of delineation would also allow for more specific survey questions resulting in concrete data.

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