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Synthesis Report on the **Application of Temporary Orange Pavement Markings in Work Zones**

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Executive Summary

The American Traffic Safety Services Association (ATSSA) is committed to reducing work zone injuries and fatalities through promotion of innovation in work zone traffic control. ATSSA accomplishes its mission in part through a complex structure of committees and subcommittees. The ATSSA Pavement Marking Committee brings together individuals from various public and private organizations with different backgrounds to identify needs and challenges, share new technology and information, and discover and advocate for proven safety countermeasures.

One recent focus for the committee is the application of temporary orange pavement markings in work zones, an experimental technique per the Manual on Uniform Traffic Control Devices (MUTCD). To assess orange pavement marking practices, ATSSA created a task force focused on this innovation. Seven state departments of transportation (DOTs) have applied orange pavement markings in various configurations to improve work zone safety for the traveling public.

This document synthesizes the application of different types of temporary orange pavement markings in the United States. To date, the following agencies have implemented this work zone application:

- California Department of Transportation (paint)
- Indiana Department of Transportation (paint and tape)
- Kentucky Transportation Cabinet (paint, thermoplastic)
- Michigan Department of Transportation (paint)
- North Texas Tollway Authority (thermoplastic)
- Washington Department of Transportation (paint)
- Wisconsin Department of Transportation (paint, epoxy and tape)

Orange pavement markings have also been used internationally in Australia, Canada, New Zealand and Switzerland. The international applications typically focused on efforts to match the pavement marking colors to the color of the channelizing devices and other features in use. In general, the primary focus is on alleviating the issue of “ghost” markings at permanent lane line and edge line locations that are removed for the new construction traffic pattern. One consistent theme from U.S. experiments is greater visibility of the temporary markings at locations with complex driving maneuvers such as lane shifts approaching the workspace.

The Orange Pavement Markings Task Force will use this synthesis document to provide suggestions for use by the National Committee on Uniform Traffic Control Devices (NCUTCD). The Task Force will further evaluate the projects documented in this synthesis report and comment on types of applications, patterns, roadways for use and materials most appropriate for use when applying temporary orange markings. In addition, automated vehicle (AV) considerations for this application are included in the final summary. For example, in connected and autonomous vehicle (CAV) applications, a lane shift could be potentially more easily recognizable to machine vision through the distinct color of the orange temporary pavement markings.

Interstate 5 Near Tacoma, Washington

Project Summary	
Location:	Interstate 5 (City of Fife)
Cross Section:	10-lane freeway with one high occupancy vehicle lane each way
Material Used:	15 mil Sherwin Williams waterborne paint
Configuration:	Lane line skip contrast markings (white preceding orange)
Timeline:	March 2023 – Fall 2023
Metrics:	Marking conspicuity, vehicle speeds, reported crashes, observed driver behavior, intrusions, community perceptions

The Washington Department of Transportation (WSDOT) is currently experimenting with temporary orange pavement markings in a work zone on Interstate 5 near Tacoma, Wash. in the City of Fife. WSDOT selected a project with multiple, long-duration lane shifts and lane reductions on the heavily traveled interstate to enhance driver awareness of the complex patterns and pattern changes. The project also includes several stages as a diverging diamond interchange (I-5 and SR167) is constructed and includes a fish culvert replacement project under I- 5 as part of the Puget Sound Gateway Program. This program includes projects that complete critical missing links in Washington's highway and freight network to improve freight movement and reduce congestion on local roads and highways. The Federal Highway Administration (FHWA) approved the orange markings Request to Experiment (RTE) on Oct. 18, 2022. The project is scheduled for construction from March 1, 2023 until the fall of 2023.

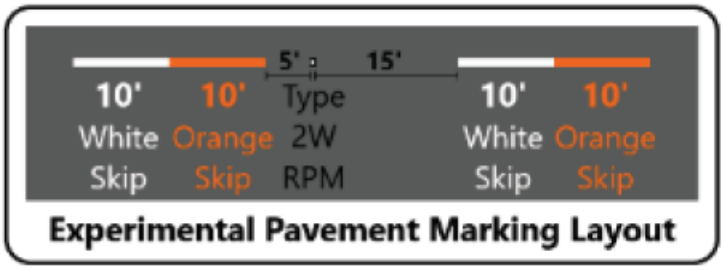

Figure 1. WSDOT Orange Marking Configuration

The project design included temporary orange contrast markings at 10-foot lengths adjacent to 10-foot white, skip-pattern markings. WSDOT also requires type 2W raised pavement markers spaced every 40 feet between the white skip lines (typically required at 80-foot intervals on interstates without construction). The pattern maintains a 40-foot skip lane line while replacing the typical gap with the 10-foot orange contrast marking. The orange contrast markings are only being used in tangent sections. Markings within the lane shifts and merge sections are traditional white prior to and beyond the workspace.

The project is underway at the time of this report and therefore, WSDOT is gathering data and observations. Performance metrics for assessment include marking conspicuity, vehicle speeds, reported crashes, driver behavior (observed), work zone intrusions (as recorded by the project office) and community perceptions to be determined based on driver surveys. WSDOT will compare before-and-after conditions based on the work zone with no orange contrast markings and the work zone with orange contrast markings.

WSDOT designed this project from a 2021-22 FHWA Work Zone Process Review and the associated findings.

Sam Rayburn Tollway in North Texas

Project Summary	
Location:	Sam Rayburn Tollway
Cross Section:	6-lane freeway
Material Used:	Type 1 retroreflective thermoplastic
Configuration:	4-inch lane line and edge line markings
Timeline:	2020
Metrics:	Retroreflectivity and chromaticity of markings, vehicle lateral position, driver opinion via surveys

The North Texas Tollway Authority (NTTA) applied orange pavement markings in a work zone on the Sam Rayburn Tollway in 2020. The tollway spans 26 miles between Business 121 near the Dallas/Denton County line and U.S. 75 in Collin County (northwest of Dallas). The project widened the 6-lane section by adding one additional lane in each direction. The first phase of the project required lanes in both directions of travel to be shifted to the inside of the roadway. NTTA applied orange pavement markings in place of all white and yellow thermoplastic markings in one direction of travel. The markings were 4-inch-wide, solid Type 1 thermoplastic retroreflective profile markings that meet the requirements of Texas Department of Transportation Item 666[1]. In a second project phase near the middle of the construction section, NTTA also applied temporary orange markings to a second lane shift.

Results indicate that the orange pavement markings deteriorate at about the same rate as traditional white and yellow. Retroreflectivity decreased for all colors of striping during construction and, after four months, the orange color evaluation shows the markings still appear as orange in color.

Of the motorists surveyed, 86% responded positively to the orange temporary markings, stating that orange markings increased their awareness of the work zone and made it easier for the vehicle operator to stay in his lane. When compared with traditional white lane line patterns, 72% of respondents noted the orange lane line pattern made it easier to stay in the lane. Most respondents (88%) noted they would like to see orange pavement markings in other work zones in Texas.

For vehicle lateral position, researchers are studying the number of edge line and lane line hits using CCTV cameras before, initially after, and one month after placement of the orange markings. Evaluation results were not readily available. The lateral position metric may show insights into potential reduction in sideswipe crash risk.

[1] https://ftp.txdot.gov/pub/txdot-info/des/spec-book-1114.pdf

Interstate 5 north of San Diego, California

The California Department of Transportation (Caltrans) installed temporary orange contrast markings in a work zone on Interstate 5 north of San Diego. This 4-mile section of interstate has a posted speed limit of 65 mph (reduced to 55 mph during construction) with an annual average daily traffic of over 200,000 vehicles per day. The pilot project used 2-inch orange stripes on each side of the traditional 6-inch white lane line in the skip pattern in the northbound direction, and a 6-inch orange stripe preceding the traditional white lane line marking in the southbound direction. In both directions, a 2-inch orange stripe was used on each side of the 8-inch white line within the gore area and for auxiliary lanes and a 3-inch orange stripe was used adjacent to the 6-inch white right edge line. The orange markings in the work zone match the pattern for traditional black contrast markings for permanent applications. The lane line pattern is a 48-foot cycle length with a 12-foot white stripe and a 32-foot gap. In the southbound direction, a 16-foot length and 6-inch-wide orange contrast line was placed in the gap after the retroreflective marker and preceding the white stripe. The markings were in place for approximately one year.

Caltrans relied on other DOT experiences to develop the experimentation plan for the layout. A vendor had a well-defined color box and data sheet for the orange paint, making implementation more streamlined and alleviating risk for the owner and contractor. The color held up well over time and Caltrans found work zone awareness benefits to orange contrast striping and plans to install it in Stage 2 of the construction project. Caltrans also experimented with tape lane lines with orange contrast along both sides. The orange faded very rapidly and might only be suitable for short-term projects. An online public perception survey was implemented and received almost 1,200 responses within a one-year period. A report on the overall evaluation results will be available in 2023.

Project Summary	
Location:	Interstate 5
Cross Section:	8-lane freeway
Material Used:	Waterborne paint at 15 mils
Configuration:	6-inch lane line contrast markings southbound (orange preceding white); 2-inch orange stripe on each side of 6-inch white lane line northbound
Timeline:	April 2022 – June 2023
Metrics:	Retroreflectivity, chromaticity, lane positioning, speeds, collisions, and driver opinion via surveys

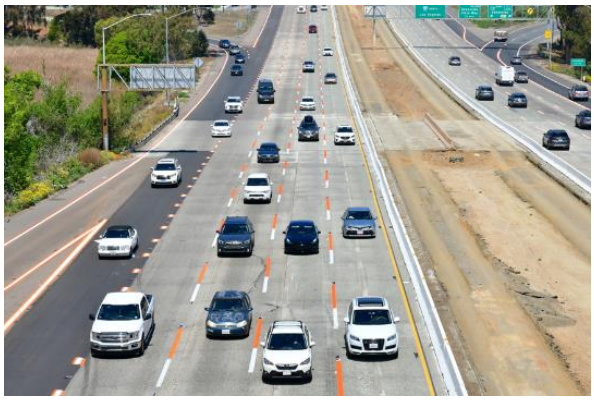

Figure 2. Orange Marking Application on Interstate 5 Southbound

Figure 3. Orange Marking Application on Interstate 5 Northbound

Interstate 96 in Oakland County, Michigan

Project Summary	
Location:	Interstate 96
Cross Section:	4-lane freeway
Material Used:	Waterborne paint
Configuration:	6-inch lane line and orange edge line markings at 22 mils
Timeline:	2022 (Summer)
Metrics:	Retroreflectivity of markings

The Michigan Department of Transportation (MDOT) applied orange pavement markings as a pilot project on Interstate 96 northwest of Detroit. MDOT included the orange markings experiment as part of a larger construction project that included installation of an active traffic management system. The project included a connected and automated vehicles (CAVs) component to test machine vision technologies and connected field devices. The project included a collaboration with General Motors to test automated vehicle (AV) technologies, including machine vision tests of the orange markings approaching lane shifts.

Figure 4. Lane Shift Pavement Markings on Interstate 96

The yellow edge line remained the traditional layout per FHWA requirements, while the skip and white edge lines were replaced with orange markings. In addition, MDOT added orange markings to shifting transition sections at crossovers. The markings were placed in mid-June of 2022 and removed at the end of October of 2022. While evaluation results are still being developed, MDOT captured initial retroreflective readings between 350 and 420 millicandelas per square meter per lux. By the end of the project, readings were between 60 and 100. MDOT developed a proposal for machine vision data collection on the approaches with orange lane lines and edge lines. As vehicles approach the shift, dashed lines turn to solid orange 300 feet prior to the transition to discourage lane changing or passing. Within the shifting taper, MDOT will evaluate the lateral movement based on the detection of orange markings. In the tangent section, the orange markings remain solid throughout the remainder of the area. This will allow assessment of lane tracking and positioning after the transition. Initial reports from the automotive companies showed no differences in reading the orange versus yellow and in some cases the systems read the orange as red in color. A full report will be released in 2023.

Interstate 75 in Kentucky (Laurel and Rockcastle Counties)

Project Summary	
Location:	Interstate 75
Cross Section:	4-lane freeway
Material Used:	Waterborne paint and thermoplastic
Configuration:	6-inch lane line and edge line markings at 15 mils
Timeline:	2019 – 2020
Metrics:	Retroreflectivity of markings, traffic speeds, crashes

The Kentucky Transportation Cabinet (KYTC) included orange markings in a construction contract for widening Interstate 75 from four lanes to six. The entire project covered approximately 20 miles, while the orange markings section was approximately 5 miles long. The other sections of the project used traditional white and yellow markings to serve as control sections for evaluation and comparison with the orange markings. While KYTC applied a combination of waterborne paint and spray thermoplastic orange markings throughout the project duration, wet-reflective elements were included at times to enhance visibility during wet conditions and nighttime conditions. Spray thermoplastic was also used to patch small areas where necessary. Striping contractors also experimented with several different types of beads.

The evaluation compared the orange marking section to the control sections, and researchers evaluated speed and crash data for each location. The work zone was present for more than a year before the orange markings were installed (November /2018 through November 2019). The evaluation compared the before condition with a one-year period after the markings were installed (November 2019 through November 2020). A baseline was established using similar sections of I-75 without work zones in addition to the control sections.

Approximately two weeks after installation, the measured retroreflectivity reading was well below KYTC's minimum standard for yellow permanent stripes and very few beads remained in the paint. The measured values further reduced by half after the winter season, and the original white markings could be seen underneath the orange markings in some areas. Spray thermoplastic was then applied at 60-75 mils with a larger gradation bead package. Later, a high-build waterborne paint marking was installed, providing even greater visibility. When evaluated 40 days after installation, approximately half of the new markings met the KYTC threshold for new yellow marking retroreflectivity.

Researchers used HERE Traffic Analytics data to calculate average speeds along the study corridor for the "before" year and the "after" year for the orange markings section and the control sections. The pre-construction posted speed limit on I-75 was 75 mph, while the reduced posted speed in the work zone was 55 mph. While some speed values increased slightly in the orange sections in comparison, the speeds between the control sections and the orange marking sections were generally similar. Average speeds in the work zone areas were also generally similar to average speeds in the non-work zone areas.

The crash analysis showed the total number of crashes increased by more than 20% in the year after the orange markings were installed as compared with the year prior to installation. This would likely be mostly attributed to the presence of the work zone. In addition, nearly the same number of crashes occurred in the orange markings section versus the control sections, even though the orange markings section was half the length of the other sections. The orange marking sections experienced a higher occurrence of rear-end crashes, with lower single-vehicle crashes. Drivers said the drop in visibility during wet conditions in the orange marking sections was problematic.

Interstate 94 locations near Milwaukee and Oconomowoc, Wisconsin

Project Summary	
Location:	Interstate 94 (Zoo Interchange) and a section near Oconomowoc
Cross Section:	4-lane freeway with limited shoulders during construction
Material Used:	Non-fluorescent paint, fluorescent epoxy, and tape
Configuration:	Lane line and edge line markings
Timeline:	2014 – 2016
Metrics:	Percentage of vehicles straddling lanes (video), visibility, driver comprehension, overall driver perception

The Wisconsin Department of Transportation (WisDOT) installed orange temporary pavement markings on I-94 as part of the $1.7 billion, six-year Zoo Interchange Reconstruction Project on the west side of Milwaukee. This interchange is a major freeway connector for downtown Milwaukee, Chicago, Madison and Fond Du Lac and carries over 350,000 vehicles per day at the intersection of I-94 and Interstate 41.

WisDOT considered the potential benefits of applying the orange pavement markings, including greater visibility for drivers, especially for lane shifts in winter conditions. However, the DOT also considered several challenges prior to implementation, including industry experience, availability of orange marking materials, specification needs and cost effectiveness.

In developing the specifications for the project, potential marking solutions included paint with standard glass beads, paint with enhanced prismatic beads, Methyl Methacrylate (MMA), and epoxy. WisDOT developed a change order for the contractor that included epoxy supplied by the DOT (in cooperation with a local vendor) with provisions for the contractor to perform the application. The experimental project request included an 18-month evaluation period, with one direction maintained with traditional pavement marking colors to serve as a control for comparison.

Figure 5. Orange Temporary Marking on Asphalt Surface

The initial application worked well and WisDOT requested that FHWA allow orange markings in both directions, which FHWA granted. After the first year of application, WisDOT requested a 2-year extension to further experiment on a bridge re-decking project on I-94. This project included a crossover with orange temporary tape installed throughout the crossover. Evaluation results showed similar metrics between control sites and the bridge deck project. From driver surveys, 27% of drivers noted the orange markings were much easier to see than white markings and 20% noted the orange markings were somewhat easier to see. Engineers also noted better visibility with the orange tape.

After several adjustments to the orange markings, WisDOT determined that using fluorescent orange epoxy from November to April worked well for winter conditions and a non-fluorescent orange latex paint supplemented by orange raised pavement markers (RPM) worked well from May to October for warm weather conditions. A less vibrant orange paint was shown to have better ultraviolet light resistance.

Additionally, WisDOT procured orange preformed tape for use in locations where small sections of the orange markings required fixes, such as where potholes may form along the painted line. The DOT also determined that a 5-inch-wide pavement marking would provide for enhanced visibility as compared with a traditional 4-inch-wide marking.

Assessment of cost effectiveness included metrics such as improved traffic safety during the winter, in addition to contractor economies of scale for volume of application. With application trucks already using traditional white and yellow paint, each application of orange required the contractor to clean the equipment prior to placement – leading to some cost increases in application. While the cost of orange markings was higher in each case, WisDOT concluded that there was enough increase in overall traffic safety benefit with use. In addition, WisDOT anticipates lower costs with more widespread use.

User surveys from local businesses showed that initial orange markings were not as visible as users expected, especially at night. The addition of the enhanced prismatic beads and higher overall material fluorescence produced an 80% favorable rating by surveyed users for the orange temporary pavement markings. Video evidence showed drivers maintained their lane better and the DOT received 95% fewer complaint calls regarding pavement markings. The percentage of vehicles straddling lanes was marginally lower under dusk and rain conditions with the orange pavement markings. Law enforcement and project staff also observed better driver navigation at the lane shifts.

Interstate 65 northwest of Indianapolis, Indiana

Project Summary	
Location:	Interstate 65 in Lebanon, Ind.
Cross Section:	4-lane freeway
Material Used:	Orange paint
Configuration:	Contrast markings
Timeline:	2023
Metrics:	Overall driver perception, lane choice, lane straddling, lane changes, crashes

The Indiana Department of Transportation (INDOT) has tested orange pavement markings (paint and tape) in several work zones across the state. One recent example is application of temporary orange edge and lane line markings on Interstate 65 northwest of Indianapolis. INDOT applied the markings on the approach to an exit where attenuator strikes in the gore area were commonly occurring. The contractor supplemented traditional white and yellow markings with orange contrast markings on the lane line (white preceding orange) and adjacent to (outside) each edge line. INDOT used the supplemental markings to address a specific safety issue at this location.

Figure 6. Supplemental Orange Markings on Interstate 65 Northbound

INDOT commissioned an evaluation of the test project using a brief public perception questionnaire with flyers placed at a rest area near the project site. Of 53 respondents, 88% reported they noticed the orange pavement markings in the work zone and 80% reported the markings made them more aware of the presence of the work zone. In addition, 81% and 82% of the respondents felt the orange markings were more visible than white markings and yellow markings, respectively.

INDOT also tested temporary orange tape at one location in Sellersburg where evaluators collected video data to observe lane choice, straddling and lane changes at a shifting taper. Lane straddle and lane change values were near zero during the observation period. Additional public perception surveys are also planned for upcoming experiments and researchers are working to develop crash modification factors and policy recommendations for the temporary orange markings.

Synthesis Summary

To date, seven agencies in the United States have experimented with temporary orange pavement markings in work zones in a variety of configurations. The following table outlines the primary layout configuration and type of material used or tested.

Table 1. Comparison of Applications by State

Agency	Configuration		Material Used			
	Contrast Markings	Full White or Yellow Replacement	Paint	Epoxy	Thermoplastic	Tape
California	●		●			
Indiana	●		●			●
Kentucky		●	●		●	
Michigan		●	●			
Texas (Tollway Authority)		●			●	
Washington	●					
Wisconsin		●	●	●		●

Several observations from the orange marking experiments are included in the list below.

- Temporary orange contrast markings may be an approach that some agencies take since permanent markings often include black contrast lines in addition to the traditional yellow and white edge and lane lines.
- Agencies are commonly using orange markings at the approaches to project lane shifts to alleviate lane straddling and improve safety, especially for larger commercial vehicles. Temporary orange marking application should be evaluated against other types of strategies, such as longer shifting taper lengths that accommodate larger vehicles (i.e., exceeding the 1/2L minimum shifting taper as outlined in the MUTCD).
- Some agencies also use wider lane lines on transitions within work zones to alleviate the potential risks of drivers missing the intended movements (even with appropriate signing).
- Future application of connected vehicle technologies will need to include further investigations to determine if the variation in color of orange markings will identify work zones or approaches to lane shifts or other more complex temporary traffic patterns.
- Guidance on line widths, material thickness and type of material best suited to long-term work zone applications could benefit decision-makers and those implementing policies for use of orange markings as a work zone safety strategy.

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