Orange Contrasted Temporary Pavement Delineation in Construction Zones

A Request to Experiment

Submitted to:

California Traffic Control Devices Committee

Submitted by:

California Department of Transportation (Caltrans)

District 11 – San Diego and Imperial Counties

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May 13, 2020

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1. Introduction

1.1 Purpose and Background

Orange temporary pavement delineation has been used around the world as a method of increasing driver awareness in construction zones. European countries, Canada, and New Zealand have implemented this striping with positive results (Reference 1). In the United States, experimentation with orange temporary delineation has occurred in three states.

The use of orange delineation may increase driver awareness of construction work zones by adding color coordination with existing construction signs and devices such as cones and drums. It can provide additional contrast to reduce driver confusion during construction staging where lane shifts often leave behind ghost lines and pavement removal scarring. In conjunction with Caltrans policy of reducing speed limits in most work zones by 10 miles per hour on the State Highway System, the orange contrast may help decrease speed differentials of vehicles in the work zone. Orange contrasted striping could also provide indication to Connected and Automated Vehicles (CAVs) and their drivers when they are in a construction zone.

Orange is not an approved color in the MUTCD for pavement delineation, so Caltrans requests permission to experiment with orange contrasted temporary pavement delineation in construction zones. The goal of the experiment is to evaluate whether using orange contrast benefits motorist and worker safety by increasing the visibility of delineation, awareness of work zones, and number of motorists driving reasonable speeds in them.

2. Previous Related Studies

Orange temporary pavement delineation has been used previously by other countries and states in construction zones.

2.1 Ontario Ministry of Transportation

In 2011, the Ontario Ministry of Transportation implemented a policy to use orange temporary pavement delineation on divided multilane highways to accommodate construction staging. Orange was designated as the special color for temporary striping in construction zones to correlate with existing construction signs and devices. The goal of the policy was to reduce driver confusion from pavement removal scars, promote safety, increase visibility in both daytime and nighttime, provide improved performance from white temporary delineation, and to provide another visual cue for the construction zone. The orange striping began at the start of the alignment transition and continued through the length of the work zone up to where traffic returned to the original alignment. Ontario used two different materials for orange temporary pavement delineation: field reacted polymeric and paint. Field reacted polymeric was preferred in situations with over 50,000 Annual Average Daily Traffic (AADT) or greater than 4 weeks of

stage construction duration. Paint was used on asphalt surfaces with under 50,000 AADT and less than 4 weeks stage construction duration (Reference 2).

2.2 WisDOT Zoo Interchange

In December 2014, the Wisconsin Department of Transportation (WisDOT) began experimenting with orange temporary pavement delineation at the Junction of the I-94, I-894, and I-41/US45, also known as the Zoo Interchange (Reference 1). All edge lines and skip lines in the experiment limits were striped orange. The Zoo interchange experienced high vehicle volumes up to 350,000 vehicles per day. WisDOT initially received permission from Federal Highway Administration (FHWA) to test orange delineation for 18 months; an extension was granted to continue experimentation through August 2018. Orange paint and epoxy were included in the bid package in the later phases of the Zoo Interchange project along with an extra bid item for cleaning out the paint truck (Reference 1). The project required hundreds of traffic stage changes resulting in numerous pavement marking applications and removals (Reference 3). Collision rates within the orange-striped work zones stayed relatively equal to white-painted work zones, even though lane shifts in the orange zones were more prevalent. Law enforcement at the Local, County and State law levels were in support (Reference 4).

Several items, such as color fading, reflective bead retention, frequent changes in lane configurations and alignments, recurrent congestion, and the use of advance work zone traffic management strategies, complicated the evaluation of the orange delineation. In 2016, WisDOT expanded their experimentation to an isolated environment through a bridge re-decking project on I-94. One bridge used orange pavement delineation tape while another bridge used the standard white colored pavement delineation. By comparing the two sites, WisDOT found that there was no significant difference in lane position. However, a lower percentage of vehicles straddled the orange pavement delineation during dusk and rain conditions. Vehicle speeds were about 2 miles per hour faster at the site with orange pavement delineation; however, the sample size was small and geometric differences between the sites may have confounded results (Reference 5).

For the Zoo Interchange project, quantitative analysis did not show significant differences between orange and white delineation; but survey results showed a more noticeable difference. Survey results from the WisDOT experiment showed successes in keeping drivers within lanes and increasing their awareness of the construction work zone. After initial application of the orange delineation, WisDOT felt that a more fluorescent shade would increase visibility. A second shade of striping was used called “orange-2” that utilized a fluorescent formula (Reference 6). The experiment received overall positive feedback from the traveling public: 80% of surveyed drivers felt that the orange-2 lane delineation increased awareness of being in a work zone, 83% of surveyed drivers indicated that orange-2 striping was more visible than traditional white, 75% of surveyed drivers liked the orange delineation while 25% thought the orange was too dark or difficult to see. Some drivers commented that they could see normal white/yellow lines better than the orange delineation in the work zone (Reference 4). Overall, driver confusion was reduced with the orange delineation, and there was a significant reduction in complaints about lane markings from when the work zone was marked in white and yellow (Reference 3).

The WisDOT study recommended water-based paint rather than epoxy paint in warmer weather due to its resistance to UV exposure and increased visibility in wet conditions. Water-based paint was 30% of the cost of epoxy and provided easier cleaning and wider availability of paint trucks. WisDOT recommended supplementing the water-based paint with raised pavement markers. For orange pavement delineation to be adopted by the MUTCD, it would need to be successful year-round. At that time, FHWA was interested in having a warm weather state experiment with orange striping to progress towards getting it approved as a pavement delineation color option nationwide (Reference 1).

2.3 New Zealand Transportation Agency

In 2014 and 2015, New Zealand Transportation Agency (NZTA) experimented with orange temporary pavement delineation on six projects in Auckland, New Zealand. In the experimental projects, the white striping was removed, and orange temporary tape or paint was applied in the work zone. Two projects lasted 9 to 14 months and four projects lasted 3 to 5 months. The goal of the projects was to reduce driver confusion from ghost lines during lane shifts. According to A. Stevens of Auckland Motorways, the demonstrations were highly successful and public acceptance of the delineation was strong. Traffic control center operators suggested that lane discipline may have been better than usual where the orange striping was used (Reference 7).

2.4 North Texas Tollway Authority

In August 2019, the North Texas Tollway Authority (NTTA) began experimenting with orange temporary pavement delineation on the Sam Rayburn Tollway (SRT). The project used 4-inch wide, solid orange, continuous profile thermoplastic pavement delineation (bumps spaced at 18 inches) to shift lanes during construction. NTTA engaged Texas A&M Transportation Institute (TTI) to assist with collecting and analyzing data to report the findings to the FHWA in semi-annual progress reports for the duration of the experiment. The primary measures of effectiveness being studied are vehicle lateral position (e.g., number of edge line and lane line hits), retroreflectivity and color values of the orange profile pavement delineation, and driver opinions. Data has been collected on vehicle lateral position using CCTV cameras before, initially after, and one month after the delineation was placed. The research team is using a retroreflectometer to capture retroreflectivity readings of orange, white, and yellow profile delineation within the work zone. Retroreflectivity has decreased as expected for all orange, yellow, and white striping. To perform color evaluation, a handheld spectrophotometer is being used. Readings are being taken at approximately two-week intervals initially and then one-month intervals. 4 months after installation, all delineation has faded, however, visually the orange delineation still appears orange. Surveys are currently being disseminated to drivers by NTTA. The project is still in progress, and final results of the experiment have not been published (Reference 8).

2.5 Kentucky Transportation Cabinet

In October 2019, FHWA approved Kentucky Transportation Cabinet's (KYTC) request to experiment with orange temporary striping on a widening project on Interstate-75 in Laurel County. The project replaced the yellow and white striping with orange lines in construction zones. The project also included wet-reflective elements in the pavement markings and supplemented the lines with orange temporary pavement markers at critical decision points such as tapers and median crossovers. KYTC is working with the University of Kentucky Transportation Research Center to conduct research on the orange striping. The work zones in the project limits are approximately 4.3 and 7.3 miles long. There was concern that the long segments would cause drivers to forget that they are still within the work zone. In addition to the orange striping, 8-foot tall letters will be painted on the pavement to show a 55-mph speed limit. KYTC hopes that this experiment will improve highway safety and encourage better driver behavior. The orange striping seems to have been received well by the public (Reference 9 & 10).

3. Evaluation Plan

In the above examples, orange temporary striping was used instead of the regular white and yellow. Sometimes enhancements like solid lines, raised profile thermoplastic material and/or pavement markings were included. For Caltrans' proposal, orange would be the contrast color to enhance standard temporary pavement delineation.

3.1 Proposed Experimental Striping

Caltrans District 11 proposes to use orange contrasted temporary pavement delineation on one or more Highway Phase units of the Interstate 5 (I-5) North Coast Corridor (NCC) Construction Project in San Diego County [see Figure 1]. Throughout the project limits on I-5, there have historically been high vehicle volumes over 200,000 AADT. For Unit 4, which has not started construction, the striping with orange contrast would be implemented from Palomar Airport Road to State Route 78 (SR-78). Standard temporary white striping has been used during the construction of Units 1, 2 and 3 of the I-5 NCC Project. These projects, particularly Unit 3 immediately to the south, would allow for comparison to evaluate the effectiveness of orange contrast with the temporary delineation in Unit 4.

Two orange contrast alternatives would be used on the I-5 Unit 4 NCC Project. Alternative 1 would be installed in the southbound direction, and Alternative 2 in the northbound direction. Alternative 1 has a 16'-long 6"-wide orange contrast line preceding the 6" white Detail 12 lane lines [see Figure 2]. Alternative 2 has a 2"-wide orange contrast stripe along both sides of the 6" white lane lines and along both sides of the 8" white lines in Details 36, 36A, 36B, 37, and 38B for gores and auxiliary lanes [see Figures 3A and 3B]. With the 6" white Detail 27B right edge line, Alternative 2 has 3" orange contrast stripe along the outside. This right edge line detail and the Alternative 2 gore details would also be used in the southbound direction.

Water-based paint is anticipated to be used instead of epoxy paint for the orange pavement delineation due to lower cost and better UV resistance. Temporary tape striping might also be used for the Alternative 2 lane lines with orange contrast along the sides.

In May 2017, Caltrans issued a memorandum entitled “Implementation of Six-Inch Wide Traffic Lines and Discontinuing Use of Non-Reflective Raised Pavement Markers”. This memorandum required all longitudinal traffic lines for lane lines, edge lines, and centerlines on State highways to be 6 inches wide. Alternatives 1 and 2 have 6” stripes in accordance with Caltrans Standard Plans [see Figures 2, 3A, and 3B]. And with this proposed temporary pavement delineation for a construction zone, orange contrast would be used like black contrast is often used with permanent striping.

3.2 Data Collection and Analysis Work Plan

The evaluation of the orange contrasted temporary pavement delineation for the I-5 NCC Unit 4 Construction project and possibly one of the other ongoing project zones includes these elements:

- The project would be monitored by closed-circuit television (CCTV) cameras allowing observation of motorist behavior through the construction work zone.
- Dashboard camera video of the work zone would be recorded during daylight, evening and night hours for driver perspective of the delineation.
- Surveys of the public would be conducted to collect data on work zone awareness and visibility of the pavement delineation and any preferences regarding the two alternatives.
- Researchers working for Caltrans DRISI would be able to put a survey for motorists to access by a link on the I-5 NCC Project website.
- DRISI researchers would collect and analyze data for vehicle lateral position in lanes, and chromaticity and retroreflectivity values of the orange contrast when first installed and at approximately 6-month intervals afterwards.
- Caltrans construction personnel and California Highway Patrol (CHP) would be consulted for collision occurrences and speed of vehicles in the construction zone.
- Data available for collision rates, speeds, and speed differentials from Unit 1, 2, and/or 3 NCC Projects without orange contrasted striping would allow for comparison with Unit 4 and/or one of those where it is added.
- Caltrans District Public Information Office (PIO) and the I-5 NCC Project (KeepSanDiegoMoving.com/BuildNCC) would inform the public prior to the implementation of the temporary striping with orange contrast.
- CHP collision reports would be reviewed to see if the orange striping was mentioned.
- Companies involved with CAV technologies could test whether orange contrasted striping is beneficial for indicating to CAVs when they are in a construction zone.

3.3 Experiment Schedule and Reporting

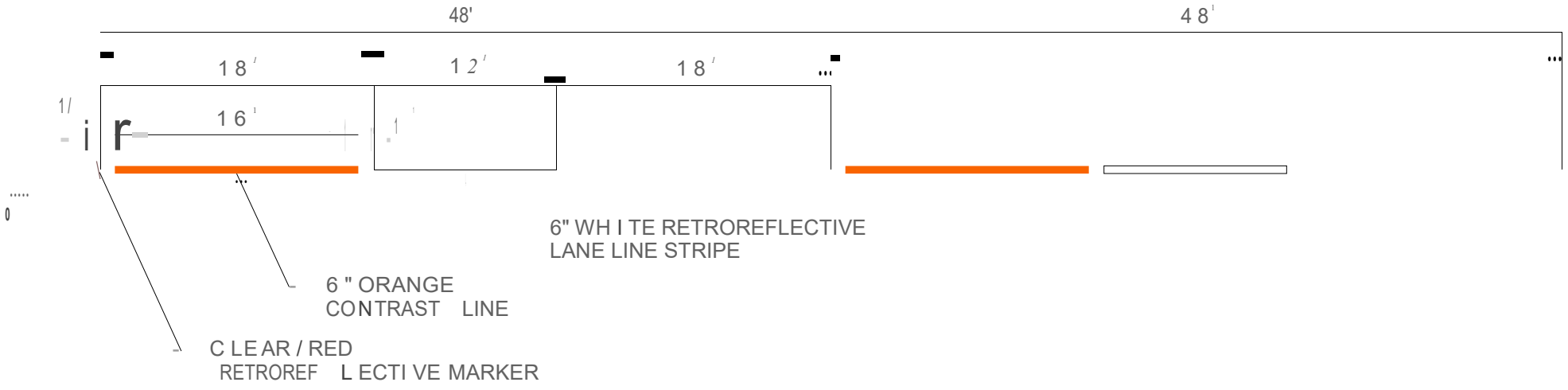
The proposed evaluation schedule would be:

- May 2020 to September 2020 – Caltrans District 11 requests to the FHWA Office of Traffic Operations and the California Traffic Control Devices Committee (CTCDC) for permission to experiment with orange contrasted temporary pavement delineation in construction zones.
- July 2020 to December 2020 – Caltrans DRISI develops a contract for formal research of the orange contrasted temporary striping.
- September 2020 to December 2020 – Orange contrasted temporary pavement delineation installed as the striping on one or more of the I-5 NCC projects.
- January 2021 to March 2022 – Striping with orange evaluated for at least one year, and the data collected analyzed to consider its effectiveness for work zones.
- May 2022 – Caltrans reports back to the FHWA and CTCDC on the status of the evaluation of orange contrasted temporary pavement delineation in construction zones.

4. Figures

Figure 1 – North Coast Corridor Project Limits

Source: https://dot.ca.gov/-/media/dot-media/programs/design/documents/11-2t17-sd-5-a11y.pdf



ORANGE CONTRAST LINE
PRECEDING LANE LINE STRIPE

FIGURE 2: ALTEAN ATIVE 1

D1s1' I COUNTY I ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

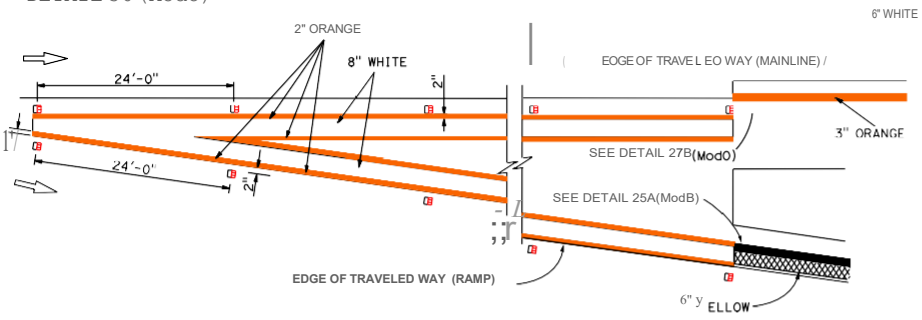
PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED VERSIONS OF THIS PLAN SHEET

REGISTERED PROFESSIONAL ENGINEER
TIMOTHY T. BROWNSON
No. 48861
Exp.09-30-18
CIVIL
STATE OF CALIFORNIA

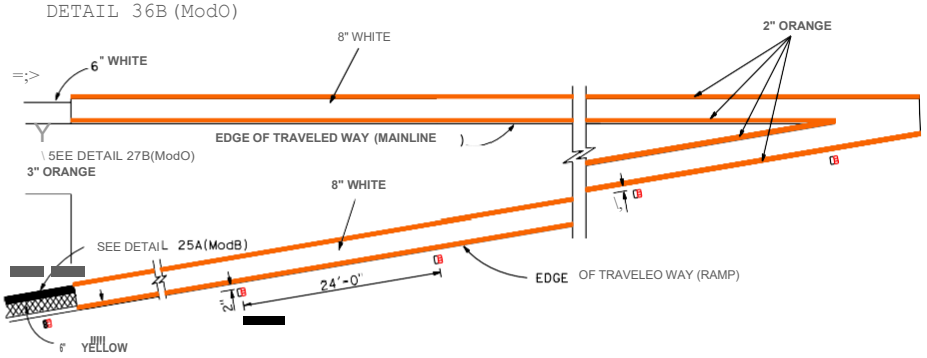
EXIT RAMP NEUTRAL AREA (GORE) TREATMENT

DETAIL 36 (ModO)



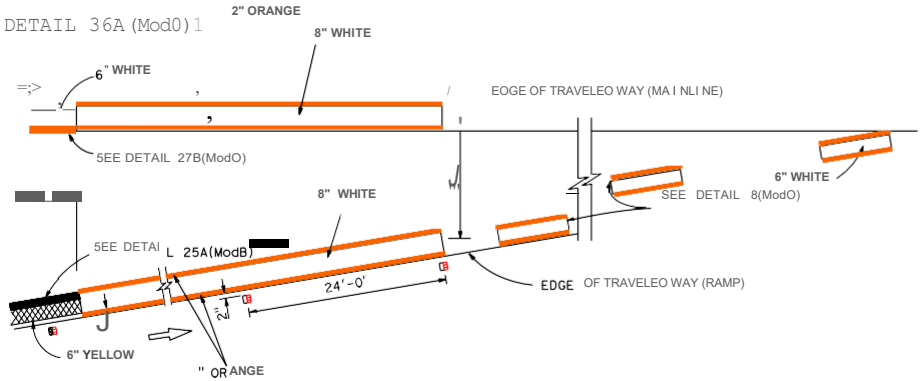
ENTRANCE RAMP NEUTRAL AREA (ACCELERATION LANE) TREATMENT

DETAIL 36B (ModO)



ENTRANCE RAMP NEUTRAL AREA (MERGE) TREATMENT

DETAIL 36A (Mod0) 1



LEGEND

MARKERS

rn TYPE CR CLEAR-RED RETROREFLECTIVE

!ilJ TYPE YR YELLOW-REO RETROREFLECTIVE

LEGEND

8" WHI TE STRIPE WITH 2" ORANGE STRIPE ON BOTH SIDES

6" YELLOW STRIPE WITH 3" BLACK

6" WHITE STRIPE WITH 3" ORANGE

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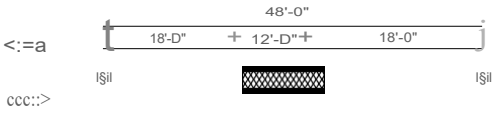
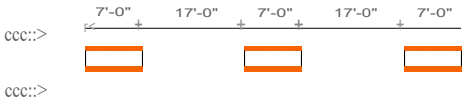
CENTERLINES
(2 LANE HIGHWAYS)

DETAIL 6 (ModB)

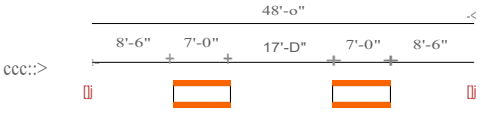


LANELINES
(MUL TI L ANE HIGHWAYS)

DETAIL 8 (ModO)



DETAIL 9 (ModO)



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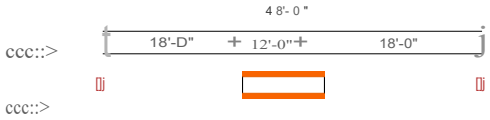
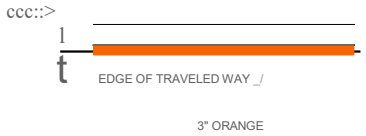


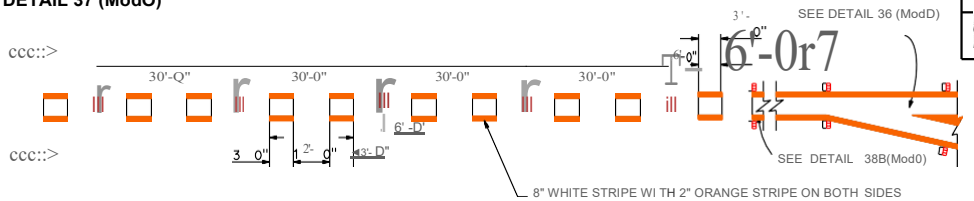
RIGHT EDGELINES

DETAIL 27B (ModO)



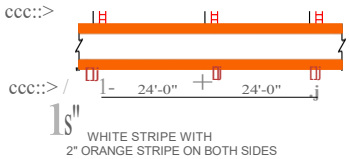
LANE DROP AT EXIT RAMPS

DETAIL 37 (ModO)



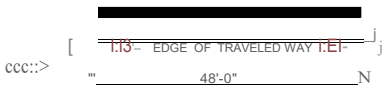
CHANNELIZING LINE

DETAIL 38B (ModO)



LEFT EDGELINES
(DIVIDED HIGHWAYS)

DETAIL 25 (ModB)



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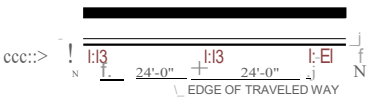

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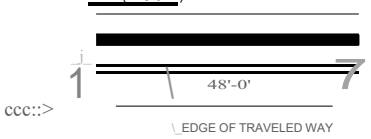

LEGEND

- 6" WHITE STRIPE WITH 2" ORANGE STRIPE ON BOTH SIDES
- 6" Y ELLO W STRIPE WITH 2" BLACK STRIPE ON BOTH SIDES
- 6" YELLOW STRIPE ON BOTH SIDES OF 3" BLACK
- 6" YELLOW STRIPE WITH 3" BLACK
- 6" WHITE STRIPE WITH 3" ORANGE

LEGEND

MARKERS

- TYPE CR CLEAR-RED RETROREFLECTIVE
- B8J TYPE D TWO-WAY YELLOW RETROREFLECTIVE
- IIEi TYPE YR YELLOW-RED RETROREFLECTIVE

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

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5. References

1. DuPont, B. (2019). Wisconsin Department of Transportation. (2019). Orange Pavement Markings. PowerPoint Presentation. 2019 ATSSA Midyear Meeting.

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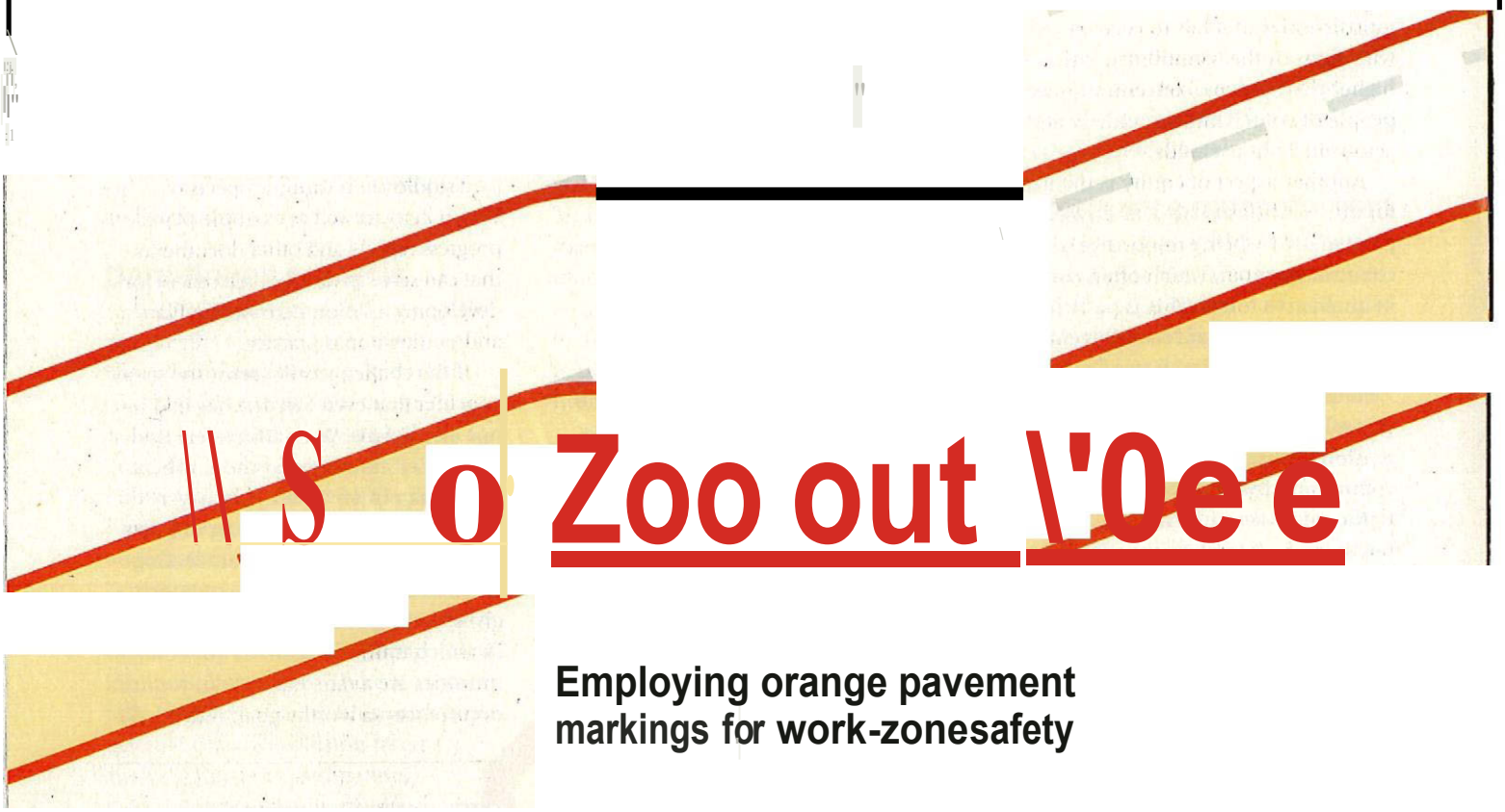
10. Barber, A., Calebs, M., Wolfe, J. Request to Experiment with Orange Pavement Markings. Commonwealth of Kentucky Transportation Cabinet. August 23, 2019.

6. Attachments

Attachment 1 – “It’s a Zoo Out There” by Brian DuPont, P.E.

Attachment 2 – “Why Drivers are Seeing Orange in Wisconsin” by Allan Heydorn



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Employing orange pavement markings for work-zonesafety

Almost 100 years ago, in the fall of 1917, June Mccarroll implemented an idea to designate roadway lane by painting a mile-long white line down the center of a highway in California..

By Brian DuPont, P.E.
Contributing Author

She campaigned for this idea to be employed statewide, and in 1924 the California l-lighway Commission agreed, au thorizing 3,500 miles of lines to be painted, It did not take Icing before the idea was adopte 'worldwide.

Recently the Wisconsin Department ofTransportation (WisDOT) took a pavement marking idea that many countries around the world have been using for many years, and incorporated it into the Zoo Interchange Reconstruction Project, the largest highway reconstruc-tion project in the state: the use of orange pavement markings **in** the work zone.

Challenges of winter work zones

The Zoo Interchange (Zoo IC} is the highest volume interchange in Wiscon-sin **with** over 350,000 vehicles per day traversing the intersection ofI-94 and I-41 on the west side of Milwa ukee. The **\$1.**7 billion reconstruction of the Zoo IC is a six-year project with work occurring year-round .

The frequent stage changes :needed to maintain traffic (more than 100 in the last three years) cause nl,lm erous pavement markings and removals, which scar th e pavement and make it difficult for drivers to maintain their lanes. Many times the scars left by removing markings leave white lines (polished surface on concrete or fractured white aggregate in asphalt) that resemble pavement marking lines, which confuses drivers. In addition to the scarred pavement, the area is heav-ily salted in the winter months duri ng snow-removal operations. The salt residu e masks white pavement mark-ings and drivers cannot distinguish lane shifts, even on sunny dry days.

This situation caused significant safety issues in the winter of 2013-14. Drivers made hundreds of calls complaining that they coutd not see the white lane lines while driving through the work zone for bridge construction over the freeway. Area news outlets highlighted the issue in articles and1V

The zoo Interchange project is the largest in W sconsin at $1.7 billion, and bears the state's most complex work zone.

reports which showed video of drivers who did not maintain their- lanes while traversing lane shifts. When the pavem nt markings were difficult to recognize, drivers looked to other cues to maintain vehicle position, like joint lines or normal shoulder distance to a barrier wall. These efforts were counter-prod1,1ctive in lane shifts that crossed pavement joints and utilized the shoulder pavement du to a work zon'e on the opposite side of the freeway.

The result was that drivers unknowingly moved into adjacent lanes and caused many dose calls with vehicles that were able to follow the work-zon: lane alignments. Drivers requested that the lanes be remarked, but what was needed was contrast **with** th!"! salt residue. Contrast markings (white on blad<) were considered, but this would involve another marking operation in the short time frame of overnight closures in cold conditions. .

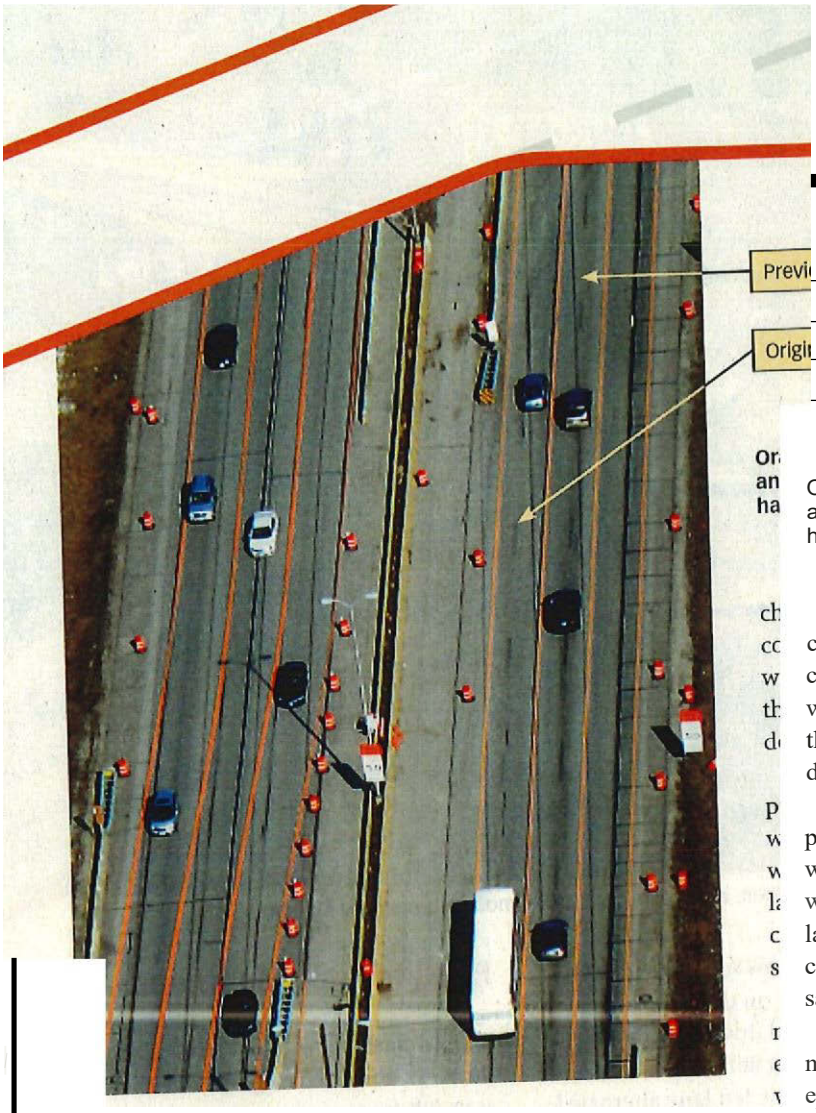
WisDOT Opl;!rations staff captured compelling video from freeway traffic cameras which showed that drivers could not follow the lane shifts on a sunny dry day in February 2014. The white lane lines were almost invisible to the morning commuters due to the combination of low sun angle and the dried salt residue on the pavement. The video showed drivers in the right two lanes merging at a lane shift, while drivers in the left lane alternated between following the shift onto the shoulder and following the old joint lines. This causedqueues several miles long, as **if** there was an unforeseen lane closure. At times there was 15-20 ft between vehicles **in** adjacent laries, and both drivers were not sure who was in the correct position. Video from the same night showed that the lane lines could beseen with area street lighting and all vehicles maintained lane discipline while traversing the same lane shift.

The daytime video showed the yellow left-edge line which helped some of the drivers in the left lane to follow the shift. This video convinced project management that the issue was not a matter of refreshing the temporary 'white markings, but that they could not be seen in some of the winter conditions. If yellow could be seen, then perhaps another color could work well in winter. Hence, the orange color used for work-zone signs and barrels was considered for work-zone pavement markings.

Request to experiment

WisDOT had considered the use of orange markings as a way to distinguish the work-zone markings from the scars left from marking removals, but decided in the design phase that the problem was not worth the cost to implement a new pavement marking color-. Sincl;! orange was not an existing pavement marking color fo the Manual on Uniform Traffic Control Devices (MUCTD), a Request to Experiment (RTE) to the Federal Highway Administration (FHWA) would have beeri required. Once the winter conditions were actually experienced in the construction phase, the idea to use orange markings gained significant traction in the spring of 2014.

Many European countrie , as well as Canada, have beeri using orange markings successfully in work zones for many years, regardless of weather. '(In Switzerland the old markings are not even re moved!) Drivers there know once you see the orange markings you are to ignore the old white (and yellow) marldngs. Canada only uses orange



Orange lane markings were shown to alleviate driver confusion and, as a result, Increase safety, particularly In **areas** that have had multiple lane shifts and marJ<ings.

on b arrier-separated.freeways; WisDOTused their exam ple and justifi cation in its RTE to FHWA.

FHWA was contacted to see if work-zone-specific pavement markings had been tested und er a previous experiment. They indicated that it had not been requested as of yet, but they had an interest in the concept. As part of the evaluation WisDOT proposed to survey drivers, construction staff and law enforcement to get their feedback. Evaluatio ns would be mad e on traffic operations, ,work-zone crashes and color retention/reflectivity of the markings. Video from freeway traffic and drive-through dashboard cameras also would be reviewed. Snow. events and associated clearing operations would be tracked. The experiment was requested for 18 months to evaluate the .concept through two winter seasons. FHWA approved the RTE in just over two weeks, with a minor revision that one direction be maintained as white markings to serve as a "control sectio n.[11]

Implementing orange

WisDOT did not have a specification that detailed the retj_uirements for orange pavement markings. Contacts were made to paint manu facturers. In most cases there was little interest in producing a new color for a limited production volume. WisDOT arranged to supply the orange epoxy paint, and the contrg.ctor just provided a price for application. Since the pavement-marking subcontractor only had two epoxy trucks (for white and yellow), a trud c cleaning charge also was included for each application. Installation of cold-weather lane shifts meant that the ambi ent temperature would be well below manufacturer's recommendations , so the contractor and supplier were not responsible for any delamination of the markings.

WisDOT procured epoxy paint from Epoplex, which had produced orange markings for Canada and was willing to work toward a successful experiment. The cost for the epoxy was about 50% higher than white and yellow and the installation was double the cost, but the project team deemed the·se costs reasonable while in pursuit of a long-termsolution for a safe winter work zone.

The first application of orange work-zone markings was made on Dec. 6; 2014, with air temperalur es of25°F. The epoxy adh ered, and drivers maintained the lane s driving the work zone. The color of orange was not as bright as had been anticipated, however, and contact was made with Epoplex to create a more "fluorescent orange.[11]

Online surveys were requested from drivers that had traversed the work zone, and WisDOT receivedover 1,600 responses (see Figure 1): The n:iajority of respondents said the color needed to be improved, which reinforced the need for a morevibrant color. The ad mowledgement of enhanced work zone awareness also supported continued use, regardless of the time of year.

Going fluorescent

The second application of orange markings occurred in March 2015 and utilized a fluorescent formula that increased the paint cost by 30%. The new formulation was a vast improvement, as was reflected in a follow-up survey of the same respondents who participated in the initial survey (see Figure 2). Drivers overwhe lmingly supported the new fluorescent orange and preferred **it** to white and yellow. Awareness of the work zone increased from 54% to 81%. The Zoo IC Project Team thought these were great results and submit ted a request to FHWA to continue the experiment through the remainder of the pro ject. FHWA concuued and the orange markings were approved to be installed through August 2018.

The fluorescent orange began to fade significantly in May 2015 when the markings were exposed to more direct sunlight. Epoplex explained this was the trade-off for the fluorescent color, the formula was not resistant to ultraviolet

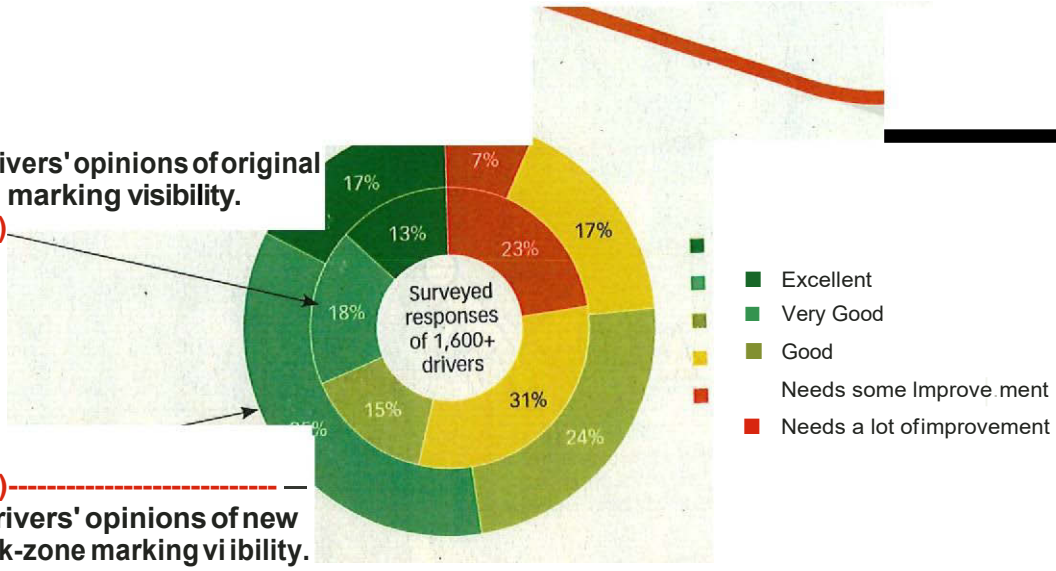


Figure 1: Drivers' opinions of original work-zone marking visibility. (inner ring)

(outer ring)---------- — Figure 2: Drivers' opinions of new orange work-zone marking visibility.

light (UVL). Epoplex began to work on a more color-fast formula. In the meantime, the pavement-marking subcontractor no longer wanted to paint orange epoxy, due to the time and effort it took to clean out the orange from their trucks. They were willing to employ water-based orange latex paint, because the effort to switch colors was minimal. In the non-winter months, WisDOT also was interested in latex orange, so as to maintain color continuity benefits while significantly reducing the material and application costs.

Epoplex does not produce latex paint, so WisDOT reached out to Diamond Vogel, which had shown interest in the experiment. They attempted to produce a florescent orange, but determined it <1lso would fade in UVL. They produced a color that was brighter than the initial epoxy but was noticeably darker than the fluorescent epoxy. To supplement these markings, the project team installed orange-plastic raised pavement markers (RPMs). This combination oflatex and RPMs worked well until the following winter when the .. fluorescent epoxy was used again .

In fall of 2015, WisDOT awarded its largest contract ever- $300 million for the core of the Zoo IC. WisDQT took all the knowledge learned under the first contract and developed items and specifications to bid on to reduce the cost. This contract included bid items for installing both orange latex and epoxy. Once again, WisDOT arranged for the procurement of the markings. Since the marking contactor had bid on placing orange markings, this contract was used to do the remainder .. of any orange markings on the entire project.

Upgrading the reflectivity

The fall of 2015 was particularly wet, and the project received numerous complaints that the orange lines were hard to see in wet weather. Temporary markings for work zones use regular glass beads that are less costly, due to the limited amount of time they are in place.Drivers would see permanent white/yellow epoxy paint with retroreflective beads priort oand after driving through the work zone and thought white/yellow was rpore visible in wet conditions than orange markings with regular beads. Therefore,they thought the white/yellow was a better color. Unfortunately, theywere not comparing similar products that happened to be different colors. In order to improve the retroreflectivity of the orange markin gs, permanent retroreflective beads were installed on all epoxy markings beginning in December 2015. Epoplex also produced an orange that was not asvibrant, but had better resistance to UVL.

Measuring performance

WisDOT also sponsored a Smart Work Zone Deploy - ment Initiative (SWZDI) grant to study orange markings on a separate project about 20 miles west of Milwaukee in late summer 2016. This study involved two separate crossovers to reconstruct bridges about 2 miles apart. One cros over was marked in white/yell w and the other if!- fluorescent orange. The markings were wet-reflective temporary tape produced by Brite-Line. In addition to stationary and drive-through dashboard video, the pro j'ect utilized side-fire distance meters to determin e if drivers maintained their lanes better in orange than white/yellow. Vehicle speeds als9 were measured. The final report on this experiment conducted by the University of Wisconsin has not been finali zed at this time.

The analysis of data to determine which color provid es better performance of drivers traveling 50-70 mph through work zones is very difficuit. Erratic driving behavior in the work zone could be from many factors, such as changing traffic patterns, narrow lanes and shoulders, and proximity to large construction equipment. The conclusion of the Zoo IC Project Team is that the confusion of drivers in winter conditions was greatly 9-iminished with the orange mar ings. Surveys document ed that drivers preferred the orange markings (once the color was more fluorescent) because it minimi zed their confusion with old pavement marking scars, regardless of the time of year. Law enforcement overwhelmingly endorsed the new markings, which had greatly reduced complaints .

Ryan Luck, the Zoo IC chief engineer, said, "We haq. a safety problem diiring winter weather construction rllat we could not solve by conventional methods. The use oforange markings allowed us to make the project safer for the traveling public by providing dear direction through a complicated work zone year-round ."

That's what Dr. Mccarroll was trying to do with her groundbreaking efforts 100 years ago. **ST**

DuPontis work-zone operation engineer at the Wisconsin Department of Transportation.

AAllan_Heydo rn, Editor

Why Drivers are Seeing ORANGE in Wisconsin

CenturY- Fence. Wisconsin DOT test orange markings in work zones

IF YINI'AE A striping contractor, and particularly if you're a long-line striping contractor, it might not be too long before you'll need to add orange paint to your arsenal of marking materials.

That's because a test program outside Milwaukee, WI, has been using orange markings, both paint and epoxy, to delineate temporary lane changes within work zones on the Zoo Interchange (Zoo IC) pavement reconstruction project.

Brian DuPont, construction oversight engineer, Wisconsin **DOT** (WisDOT), says WisDOT began considering orange markings in the winter of 2014, the year the Zoo IC project began. The project involves four miles of construction in one direction and five miles in the cross direction and the interchange handles more than 350,000 vehicles a day.

"Drivers didn't seem to have much trouble in summer but in ,,vinter with snow, ice and salt on the pavement they had difficulty tracking lane shifts, following the white lines, and often stru g-gled to stay in their lanes," DuPont says.

He says WisDOT grew concerned because there were going to be almost constant lane shifts throughout the job which lasts through 2018. So they set out to provide, via a test program approved by Federal Highway Administration (FHWA), orange markings in work zones.

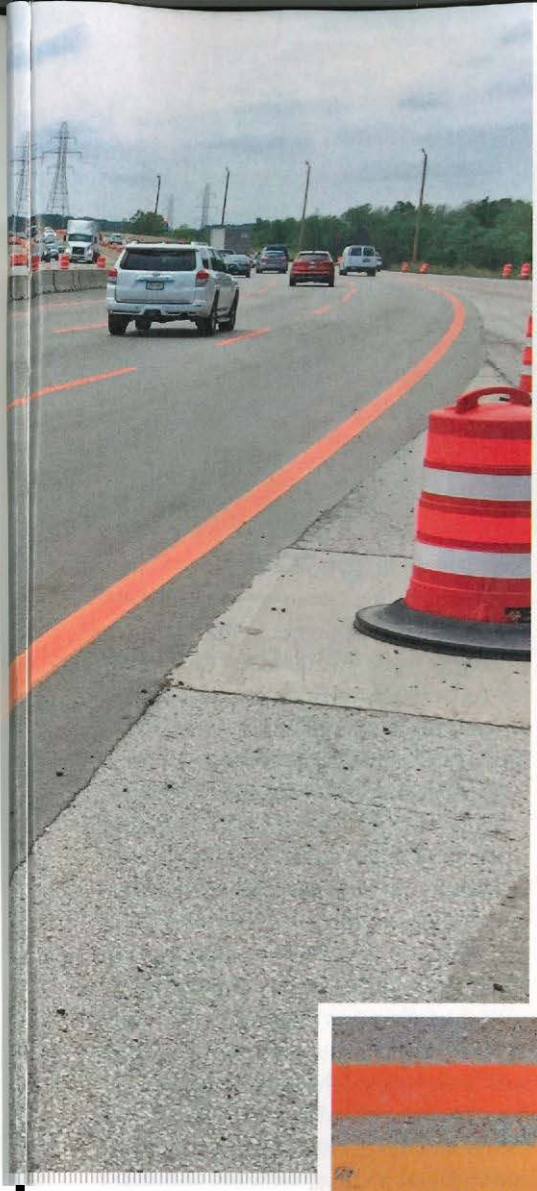
Why Orange?

According DuPont, orange markings have been used in other countries to delineate lane shifts in work zones. In Switzerland, for example, orange markings are used to delineate work zones - and they don't even remove the white lane markings. "People just know they are supposed to follow the orange and they do," DuPont says.

He says Australia uses white all the time for regular markings, and yellow all the time for work zones. "When the markings are a different color it's clearer to drivers that this is what they're supposed to follow," he says. "Orange represents work zone conditions in the United States . It's the same color as cones and drums and signs and people have told us it makes more sense."

So WisDOT recommended to FHWA that using the orange markings might make it easier for drivers to distinguish ghost lines - the lines left behind in the pavement when original lane markings are scarified - and to avoid driver confusion .

Because orange markings are not an approved process in the Manual of Uniform Traffic Control Devices



WisDOT used orange markings throughout each workzone, but Brian DuPont says another option is using the orange only at the beginning and end of the workzones indicating the lane shifts, in which case orange tape might be a preferred material.

Are Orange Markings in Our Future?

WisDOT's Brian DuPont says FHWA doesn't take into consideration weather conditions when making rules for use of marking materials, so for orange to be adopted by the MUTCD it would have to be successful year-round.

"We and FHWA would like another state - especially a warm weather state - to test it out to see if the drivers like it there as much as they did in Wisconsin," DuPont says. "If so, the orange might become an approved marking color in work zones throughout the country. We could end up making all lane shifts orange. You can see them from a long ways away."

DuPont says that another option, as opposed to orange paint or epoxy throughout the whole work zone lane shift, is to use orange marking only at the beginning and end of the lane change. "If you grab their attention for areas where it changes at both ends of a work zone then maybe that's all you need," he says.

"In that case maybe tape is the answer. Tape has the potential to be a better tool because when you're doing a shorter distance it's not worth it to fire up a paint truck with orange for 500 feet. It's better to shut the lanes down at night and put tape down and then open it up. But if you're doing miles then a truck would be best."

The same holds tr ue when smaller road repairs are needed. "If you have a repair to make that disrupts the orange marking you don't want to bring a truck out there filled with orange paint to replace a 12-foot line over a pothole you just repaired. So maybe tape can be used to suppleme nt paint, when it's not worth it to bring a truck out there."

Seven ty-five percent of drivers surveyed think the orange markings are easier to see while 25 % though them darker. But WisDOT thinks the 25% are reacting to the fact that white and yellow markings had no beads - so beads were added to the orange markings.

(MUTCD), WisDOT had to get permission from FHWA to use orange. DuPont says that after some negotiation **FHWA** approved a test of the orange markings for 18 months. Seven months into the test WisDOT went back to FHWA to ask them to extend the pem1ission through the completion of the project in 2018, which they did.

Orange markings are now used in work zones throughout the entire project - that's more than 100 lane shifts since 2014 where a typical project would include only three or four lane shifts. DuPont says the construction phase requiring lane changes and orange markings should be completed by December.

Finding a Contractor for Orange

The contractor that did the first installation of orange epoxy only had trucks for yellow and white, so any time the orange installation was required they had to clean out a truck, apply the orange markings, and then clean the truck again so it could be usedfor white or yellow. The process was time consuming but worked - until spring when the marking season picked up and the contractor no longer wanted to do the work.

So WisDOT let the bid again, and Century Fence, Pewaukee, WI, got the job.

"The orange paint was part of the entire bid package for the Zoo IC project so we factored in what it would take, including use of an extra striping truck, and put the bid together," says Tim Mcchesney, vice president of operations, Century Fence. "We bid on it knowing pretty much what we were getting into."

Century Fence, which is celebrating its 100th anniversary this year, employs 100 people peak season (half devoted to striping), generates half its sales from pavement marking and the other half from commercial and DOT _fencing. In addition being responsible for the

Contr acto rs in the U.S. don't have a tr uck dedicate d to orange mater ial as they do for white and yellow. Century Fence had a truck that is used as a spare, which made it a little easier. But they still had to clean it out when it was needed for white or yellow, then again when orange was needed, which took up to a day on each end.

temporary and pennanent striping on the Zoo IC job, Century Fence also handles a good portion of the fencing on the Zoo IC project.

According to McChesney, almost all the company's pavement marking work is long-line striping and road marking, though the company does stripe parking lots when epoxy work is required. In addition to long-line striping equipment, Century Fence has a complete fleet to handle just about any pavement marketing-related job including walk-behind units for stencils and crosswalks, grooving units to install pavement markers, and waterblasting units for marking removal. He says 90% of the contractor's work is as a subcontractor.

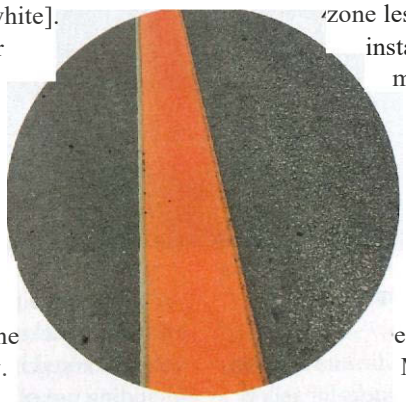
"We have one unit that is not a full-time striping unit for us. It's a spare and we put orange paint or epoxy in that as we needed it," McChesne y says. "Then when we need it on another job we clean it out - it can take up to a day on both ends [cleaning yellow/white to orange and orange to yellow/white]. But that was part of our plan and we factored that in when we put the bid together."

McChesney says that despite the additional time involved to prepare a truck for orange mate rial, the job and all its work zone striping went smoothly.

"The GC, Walsh Construction, was very good about letting us know in advance when orange markings were going to be needed so we could prepare," Mcchesney says, adding that the contractor usually got a three-week notice when orange would be needed. WisDOT also held weekly meetings every Wednesday that Walsh Construction attended at the Zoo IC office. Century Fence either had a representative at those meetings when scheduling was discussed or the general contractor let Century Fence know following a meeting when orange markings would be needed.

Mcchesney says Cen tury Fence trained six workers on the project in addition to a dedicated project supervisor. "Often just a few of the team were on the job, but when it was a bigger job and removal of old markings was required before the orange lines were placed , all six people plus the supervisor were out there," he says.

"When we first started on the project Century Fence crews were out on the jobsite installing orange work zones every week for a while," McChesne y says. "Now it's every couple of months. It gradually dwindled as they progressed on the project and need the orange zone less and less as we began installing pennanent markings."



Because orange markings aren 't used in the U.S., WisDOT and Century Fence had difficulty finding a supplier for the orange material.

Walsh Construction handled traffic control and lighting for the night, and sometimes WisDOT was able to close down the entire road to make striping easier and safer.

McChesney says all work was done at night and the striping crew had to be off the job by 5:00 a.m. or face a penalty. "So we made sure we had enough manpower on the on each night to make sure we hit the deadlines," he says.

Finding Orange Material

DuPont says that because orange is not an MUTCD-approved mar king, the color isn't readily available in the United Stat es. So after reaching out to several markings manufacturers, WisDOT turned to Epoplex, which produces an orange epoxy for use in Canada .

"But when the contractor put it down we realized it was darker than we thought and darker than we wanted - we'd seen photos and samples but it was darker than that. So we talked with Epoplex and they agreed to create a fluorescent version of the epoxy," DuPont says. "But while the fluorescent markings worked well in the winter, the ultraviolet light from the sun caused the fluorescent characteristics to fade to yellow by summer, so we ended up with confusing yellow markings all over the road."

So WisDOT began searching again for a material, eventually working with Diamond Vogel to create a water-based latex orange paint. Unfortunately it had the opposite problem - it worked well in the summer but not in the winter because it didn't stand up to the salt and weather and plowing. So WisDOT now uses the fluorescent epoxy for the winter months and latex for the summer months.

DuPont says the latex isn't as bright as the epoxy so WisDOT decided to supplement the latex markings with plastic raised pavement markers between the skip lines. These markers worked well during the warm weather, but were plowed off in the winter.

Because the orange material was not readily available, WisDOT decided they would find and supply the orange material themselves as opposed to having the contractor locate it and supply it.

"If we left it up to the contractor to

purchase we'd have to make sure it was what we wanted - and there wasn't a lot of what we wanted available to us," DuPont says. "We also supplied it ourselves because orange is not a color striping contractors use. So if there is any leftover we didn't think it would be fair for the contractor to have to keep it and absorb that cost."

So WisDOT selected the material and supplier and directed Century Fence through a change order to buy it so they could store it at the yard and load the trucks each day.

Drivers See Orange a Success

DuPont says that as of September the Zoo IC project is 80% complete and most of the main work will be done by the end of the year. "We're pretty much done putting down the orange paint, so when we move the lanes back we will remove the orange markings and install permanent white and yellow markings," he says.

He says that surveys of drivers find that 75% like the orange markings and 25% think the orange is too dark or difficult to see.

"We think drivers had trouble seeing the orange markings because when you put down temporary markings you often don't put 'high quality' beads in it because of the added expense," DuPont says.

Some people commented that they could see the white/yellow lines better when they drove out of the work zone. 'We think that people reacted when they went through the orange and then went to the white and yellow, which have better beads in them. We think they were reacting to the beads and not to the color, so we decided to put beads in the orange."

Century Fence experimented with different ways of improving visibility of the orange markings when they were wet. "We went above and beyond the standard bead package for them because that was a primary concern of the project and the drivers - they couldn't see the lines, which is why they switched to orange to begin with," McChesney says. "We tried a couple of different approaches and they chose one of them and it seemed to really help people see the lines better."

DuPont says he doesn't know whether the orange markings in work zones will catch on in the United States. But he says WisDOT will put together a report for FHWA about its effectiveness on the Zoo IC project.

"We didn't see a reduction in crashes but we didn't see an increase in crashes either as the work zone got more complicated," DuPont says. "It's a very difficult thing to measure because crashes can be caused by all sorts of things. But we are satisfied the switch to orange markings made a better experience for the majority of the driving public." **PVM**

Orange Passes Tape Test

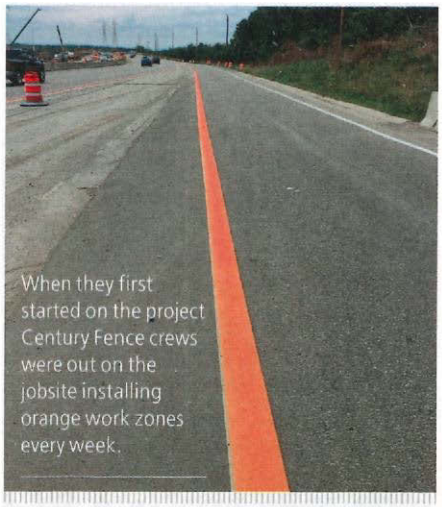
As long as they were testing orange paint they decided to test orange tape too. WisDOT's Brian DuPont says that when they realized they were going to have two lane shifts on bridges within two miles of each other they had a perfect opportunity of a test and a "control" segment.

"The traffic will go over both bridges at the same rate of speed and it will be the same traffic volume because the bridges are so close together," he says.

So rather than flipping traffic one way and then flipping it back once a side of the bridge is completed, they set up a crossover work zone in orange tape on one bridge and another crossover in yellow and white on the other bridge. Tape was from the same manufacturer so results could be as consistent as possible.

He says the University of Wisconsin tried to measure whether drivers acted differently in either section - do they stay in their lane better in the orange than the white, for example, but initial results are that there wasn't a significant distinction in driver behavior between the two areas.

"But the survey said the drivers like the orange better," DuPont says. "If drivers like the orange better it's because they can see it more clearly and it makes them feel more comfortable that they know where they're supposed to go. So the survey results are what we're going by."



When they first started on the project Century Fence crews were out on the jobsite installing orange work zones every week.

Since 2014 Century Fence's crews installed 4-inch and 8-inch orange lines in more than 100 work zones in the Zoo IC project.