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The effect of chevron alignment signs on driver performance on horizontal curves with different roadway geometries

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ABSTRACT

To develop a practicable and clear guideline for implementing Chevrons on China's highways, it is necessary to understand the effect of Chevrons on driving performance in different roadway geometries.

Using a driving simulator, this study tests the effect of China's Chevrons on vehicle speed and lane position on two-lane rural highway horizontal curves with different roadway geometries.

The results showed a significant effect of Chevrons on speed reduction, and this function was not significantly affected by curve radius but was statistically affected by curve direction. The speed reduction caused by Chevrons was also significant at the approach of curve, middle of curve and point of tangent. The 85th percentile speed was also markedly lower when Chevrons were present. We also found a significant effect of Chevrons in encouraging participants to drive the vehicle with a more proper lane position at the first half of curves; and this function was slightly affected by curve radius. Meanwhile, the effect of Chevrons on keeping drivers staying in a more stable lane position was also statistically significant at the second half of curves. In sharp curves, the function of Chevrons to make drivers keep a stable lane position was lost. Besides, the impact of curve direction on the function of Chevrons on lane position was always present, and drivers would drive slightly away from Chevrons.

Regardless of the curve radius, China's Chevrons at horizontal curves provide an advance warning, speed control and lane position guide for traffic on the nearside of Chevrons. Besides, combing with the function of Chevrons on preventing excessive speed and the benefit to make drivers keep a more proper lane position, China's Chevrons appear to be of great benefit to reduce crashes (e.g., run-off-road) in curves.

1. Introduction

Previous traffic crash statistics and research have consistently shown that the average crash rate on horizontal curves is significantly higher than the rate on straight (or tangent) sections, and most of fatal crashes on horizontal curves are run-off-road and head-on crashes (National Highway Traffic Safety Administration, 2008). Previous research also stated that an inappropriate speed choice or even speeding resulting from drivers' incorrect recognition or misjudgment of given roadway alignment features played a significant role in run-off-road crashes (Felipe and Navin, 1998). Besides, a review of the Roadside Infrastructure for Safer European Roads detailed crash database revealed that lateral positioning of the vehicle was also the primary factor leading to crashes (Van Der Horst and De Ridder, 2007). Hence, options including post-mounted delineators (PMD), Chevron alignment signs, raised pavement markers, one-direction large horizontal arrow signs, and advance warning signs have been widely implemented to improve the safety of horizontal curves (Comte and Jamson, 2000; Jamson et al., 2010).

The Chevron alignment sign is an important element of curve delineation devices, and it serves two main purposes. First, it allows for better visibility when approaching a curve and provides positive guidance while negotiating a curve. Second, properly spaced Chevrons can be helpful in encouraging drivers to reduce their speed going into and through a curve (Srinivasan et al., 2010).

In the U.S., the Chevron alignment sign described in Section 2C of the Manual on Uniform Traffic Control Devices (MUTCD) is a traffic control device typically used to warn drivers of the severity of a curve by delineating the alignment of the road around that curve (FHWA, 2009). The emphasis of past research on Chevrons in the U.S. has been on the effectiveness of Chevrons in terms of vehicle operations (e.g., driving speed and lane position) or on the criteria for more effective placement of Chevrons.

As noted by Jennings and Demetsky (1985), both driving speed and speed variance decreased when Chevrons were placed at twice the distance of the MUTCD-recommended delineator spacing.

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Besides, Chevrons also promoted desirable lateral placement. Zador et al.'s study (1987) also found a small reduction in vehicle speeds and placement variability when Chevrons were placed such that three were always in view on rural roads, and the speed data was collected 100 feet in advance of the curve and 100 feet after the beginning of the curve. In addition, the benefit of Chevrons on vehicle speed and lane position did not diminish over time. Rose and Carlson (2005) conducted a field study to investigate the impacts of varying the number of Chevrons in view on driving speed. The results showed that having more than two Chevrons in view on a curve did provide the benefit of a small reduction in average speed, and this benefit was more obvious at night.

In contrast to the study results above, Zwahlen (1993) did not find a significant speed reduction after Chevron alignment signs were installed, based on an analysis of data collected before and after the installation of Chevrons. Surprisingly, with the presence of this horizontal alignment sign, some drivers increased their speeds while other drivers decreased their speeds. Overall, a slight speed reduction was found for curves with Chevrons, but the reduction was not statistically significant. One possible reason for this phenomenon might be due to a lack of consistent guidelines regarding the type, number, and location of Chevrons for different curves.

Overall, the previous research findings on whether or not Chevrons are effective in influencing drivers' speed choice are not always consistent. But given the results of the research, it can be determined that Chevrons in the U.S. do provide some reduction in the speeds as well as speed variances. Additionally, Chevrons in the U.S. do encourage drivers to keep a more proper and stable lane position while negotiating a curve.

Unlike in other countries, the Chevron alignment sign in China is a vertical rectangle with a white arrow and border on a blue background; more detailed information about the Chevron alignment sign in China has been stated in a paper by Wu et al. (2013). China's Chevrons is shown in Fig. 1. More importantly, the effect of China's Chevron on driver behavior has rarely been studied, and the guidance for placing Chevrons is too vague, offering no clear and specific requirements for using Chevrons under various traffic, roadway and environmental conditions. The existing limited research about Chevron alignment signs in China is primarily focused on determining the optimal spacing of the country's Chevrons on curves (Zhao et al., 1998; Huang, 2004); to our knowledge, few studies have evaluated the effectiveness of China's Chevrons on vehicle speed and lane position.

As a pilot study, the effect of China's Chevrons on drivers' eye movements, driving performance (steering, braking and letting off the accelerator), vehicle operations (speed and lateral placement) and stress in given road conditions has been analyzed (Wu et al., 2013, 2012). As a result, we did not find a significant effect of Chevrons on average driving speed, but drivers' vehicle control data (e.g., braking and letting off the accelerator) indicated that Chevrons made drivers tend to decrease their speed more. A serious limitation of the study is that the experimental data was likely affected by the confounding factors involved. In that study, Chevrons were placed near the guardrail along the left-hand edge of the paved road surface. A significant interaction has been found

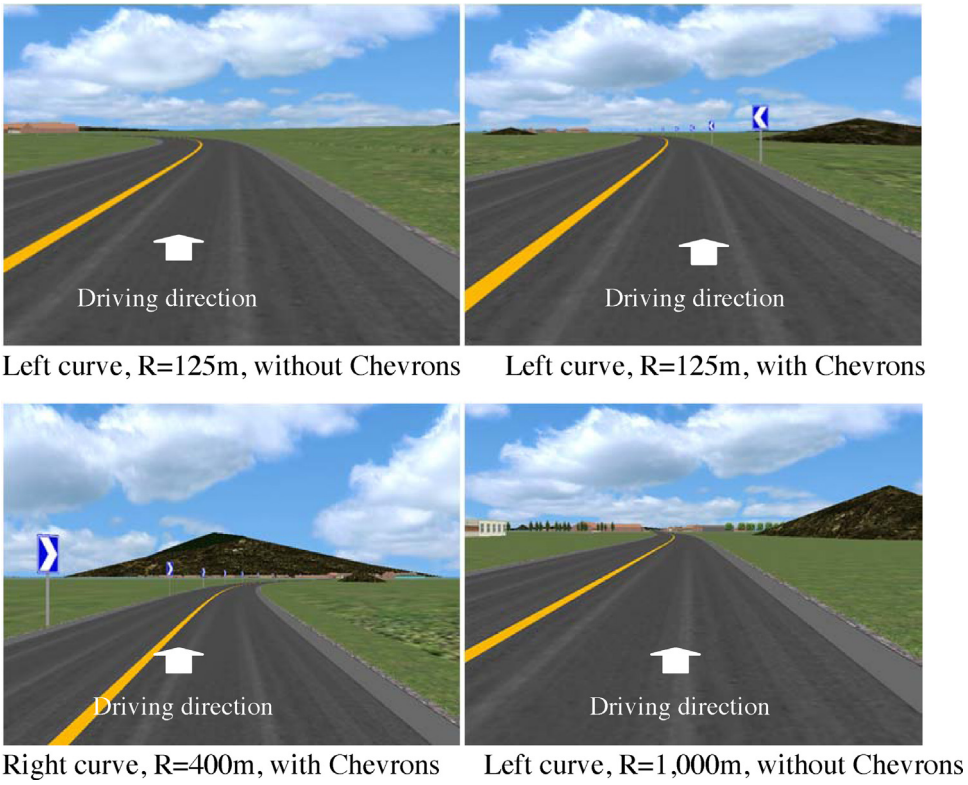

Fig. 1. Examples of screen shot pictures of various combinations of Chevron presence, curve radius and curve direction.