Abridgment

Effect of Bridge Shoulder Width on Traffic Operational Characteristics

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In 1970, West Virginia University, in cooperation with the West Virginia Department of Highways and the Federal Highway Administration, began a study to develop analytical techniques for determining the best shoulder and curb width on long-span bridge structures from the standpoints of safety and cost. The major objective of this research was to determine whether providing full-width shoulders across long-span bridge structures would improve traffic and safety. Completed in 1975, the study included a structural cost analysis, accident record analysis, a controlled laboratory study, and a before and after field study to relate the results of the laboratory study to actual field conditions. The structural cost analysis study revealed that the additional cost for widening would be about 3 percent of total bridge cost per 0.3 m (1 ft) of bridge width. The accident study revealed no strong relationship between bridge shoulder width and accidents although the laboratory study showed that erratic behavior of drivers is at a minimum for a bridge shoulder width of 1.8 m (6 ft).

The before and after field study, which is reported here, was carried out in two major stages. The first stage consisted of studying the effect of various bridge shoulder curb widths on the operational characteristics of vehicles on the bridge. The second stage consisted of making these same studies on the effects of various bridge shoulder curb widths with a guardrail type of barrier flush with the face of the curb and offset 0.6 m (2 ft) from the face of the curb.

The before condition consisted of determining the speed and lateral placement, as measured from the edge of the roadway shoulder, of vehicles in the vicinity of the bridge. The lateral placement of the vehicle is the distance of the right front wheel from the edge of the roadway at the point where the shoulder begins. After the observations for the before period were made, the physical characteristics of the bridge were altered to simulate the effect of 0.6, 1.2, 1.8, and 2.4-m (2, 4, 6, and 8-ft) curbs alone and with guardrail both flush with the face of the curb and offset 0.6 m (2 ft) from the face of the curb. This resulted in a minimum of 11 conditions in the after period.

Although the basic study was concerned with curbs as wide as 2.4 m (8 ft), this study was confined to investigating the effect of 0.6, 1.2, and 1.8-m (2, 4, and 6-ft) curbs on a bridge with 3-m (10-ft) shoulders.

The speed and lateral placement of automobiles only were collected at six locations on and in the vicinity of the study bridge under conditions of no curb and 0.6, 1.2, and 1.8-m (2, 4, and 6-ft) curbs. These various curb widths resulted in effective bridge shoulder widths of 3, 2.4, 1.8, and 1.2 m (10, 8, 6, and 4 ft). Data were collected on the speed and lateral placement of at least 200 free-flowing automobiles for each of the test conditions at six locations for a minimum of 2 days under each condition.

The site selected for study is located on Interstate 79, approximately 32 km (20 miles) south of Morgantown and just east of Fairmont, West Virginia. The nearest on-ramp is approximately 1.6 km (1 mile) upstream and the nearest off-ramp is approximately 0.8 km (½ mile) downstream. The roadway throughout the test section has four 3.6-m (12-ft) lanes, divided by a grass median. The study site is located on the southbound lane with a 5 percent downgrade.

The study bridge, which is 67 m (220 ft) long, is slightly skewed to the right and has W-beam guardrails on both shoulders on the upstream and on the right shoulder on the downstream side. This particular site was selected because it was built to AASHTO-recommended design standards, and it also possessed other qualities desirable for obtaining data.

The proper measurement of the speed and placement variables was considered to be critical to the successful completion of this study. Measurements of vehicle speed and placement were made by using a tape switch installed 305 and 152 m (1000 and 500 ft) upstream of the bridge, 152 m (500 ft) downstream, at the upstream and downstream ends of the bridge, and in the middle of the bridge. Data were collected for a 4-day period with no modifications to the bridge so as to establish the before condition. After the base data were collected, the curb

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was simulated by fabricating a wood curb to resemble the actual concrete curb as nearly as possible. The curbing was fabricated in 0.6-m (2-ft) sections so that it could be used to simulate 0.6, 1.2, and 1.8-m (2, 4, and 6-ft) curb conditions. Data were collected for each of the conditions after the traffic had adjusted to the new situation.

To evaluate the effect of position and curbing conditions on vehicle speeds and placements, a fixed effects analysis of variance model was formulated since only discrete levels of each factor were to be analyzed. The model was tested to determine whether there were significant differences between levels of curb conditions or levels of positions and for an interaction effect between the levels of curb conditions and positions.

The conclusions drawn from this study were, like any research effort, necessarily limited by many factors. As many of the confounding factors as possible were controlled or eliminated where possible so that more reliable conclusions could be reached regarding those variables of interest.

The following conclusions were reached after the results of the study were evaluated.

1. Vehicle speed and placement data may be combined for different days of the week without any major loss of information.
2. Relative location had a significant effect on speeds as the vehicles moved through the test section. Average speeds increased from 96.88 km/h (60.20 mph) 305 m (1000 ft) upstream to 101.0 km/h (62.78 mph) 152 m (500 ft) downstream, a difference of 4.12 km/h (2.58 mph). It was concluded that the increase in speed was probably due to the 5 percent downgrade throughout the test section.
3. All curb conditions had a significant effect on vehicular speeds in that the speeds with curb in place were significantly lower than those with the base condition of no curb. The lowest average speed of 97.73 km/h (60.73 mph) occurred with 1.2-m (4-ft) curbs; the speed with no curbing was 100.36 km/h (62.36 mph), a difference of 2.62 km/h (1.63 mph).
4. There is a significant interaction between positions and conditions for vehicle placements, which leads to the conclusion that some positions and conditions affect vehicle placement while others do not.
5. Vehicles travel farther from the roadway edge at the center of the bridge under all curbing conditions.
6. Vehicles travel farther from the shoulder at the center and the upstream and downstream ends of the bridge under the 1.8-m (6-ft) curb conditions. There is a small but definitely significant displacement of vehicles on the bridge for the 1.8-m (6-ft) curb condition.
7. With the 1.8-m (6-ft) curb, vehicles tend to move slightly away from the shoulder edge as they cross the bridge, then tend to overcorrect, and move nearer the shoulder downstream of the bridge.

Future research of the type conducted in this study should include, at least in the initial phase, an additional evaluation to verify the conclusion from this study that data for separate days of the week may be combined. Ideally, this evaluation should be based on speed and placement data collected for a full 5-day week as a minimum and check for significant differences between days.

The results of this study, in the context of implications for design or vehicle operations, tend to support the conclusion that the effects of bridge safety curb on vehicle speeds and placements, although statistically significant, are not practically significant, at least during daylight hours. The difference in speeds between positions can probably be attributed to the 5 percent downgrade and is therefore highly suspect. Further research in this area should be conducted on a level or near level roadway grade if possible.

Although the effect of curbing on speeds is statistically significant, the rank order of these effects creates some doubt about the practical importance of this difference. The highest speed occurred with no curb and the lowest with 1.2 and 1.8-m (4 and 6-ft) curb conditions. The higher speed with no curb is probably true, and, although the lower speeds for the three curb conditions are also true, the seemingly significant difference in speeds between the 1.2-m (4-ft) curb and the other curb conditions is probably due to chance alone. This can be verified with additional research. In this case, however, the difference in speed of 2.62 km/h (1.63 mph) between the base condition of no curb and the 1.8-m (6-ft) curbing condition is less than 4.0 km/h (2.5 mph), which can be defined as the range of accuracy for design standards. Design standards are established in increments of 8 km/h (5 mph); therefore, a change of less than half this increment would have no effect on these standards.

The conclusion about interaction between positions and conditions for vehicle placement is not surprising. Drivers definitely tend to move away from any obstacle placed near the edge of the roadway. The simulated curb on the bridge caused the drivers to displace as they approached and crossed the bridge and then to return to a position closer to the shoulder edge after crossing the bridge. In fact, drivers tend to overcorrect after crossing the bridge and to move nearer the shoulder edge than they were upstream of the bridge. This is particularly true with the 1.2 and 1.8-m (4 and 6-ft) curb conditions.

The maximum difference in vehicle placement occurred at the upstream end of the bridge and was only 0.16 m (0.54 ft). The maximum differences in placement from the other conditions at the center of the downstream end of the bridge were 0.11 and 0.08 m (0.35 and 0.26 ft) respectively. It can be concluded from these differences that the displacement of vehicles as they crossed the bridge would not be large enough to affect the lane width on the bridge.

It should be pointed out that the conclusions drawn from this study can only be applied to bridges on relatively high-speed, one-way roadways with two lanes. Two-way bridges, even though they may have two lanes in each direction, may and probably would give entirely different results.

The findings and conclusions developed from this study are significant but must be considered in the light of the many restrictions that were of necessity placed on the project. The major restrictions were as follows:

1. Only free-flowing vehicles were considered;
2. A single data site was used;
3. Only daylight conditions were investigated;
4. The test bridge was relatively short; and
5. Data were collected during fair weather conditions only.

Even with these restrictions, there is strong evidence to support the conclusion that 1.8-m (6-ft) outside shoulders on rural freeway bridges would not seriously affect the operational characteristics of vehicles as they crossed the bridge.

It is recommended that further research be carried out to investigate design factors not included in this project. If the findings of this further study support the findings of this project, then the recommendation can be made that bridge designers give serious consideration to reducing the outside shoulder width on rural freeway bridges to a minimum of 1.8 m (6 ft).

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