SAFETY ASPECTS OF ROADSIDE SLOPE COMBINATIONS

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ABRIDGMENT

•TO provide objective criteria for safe slope combinations and various ditch configurations is the specific objective of research efforts discussed in this paper.

The research approach involved simulated traversals of approximately 168 combinations of front and back slopes from 3:1 to 6:1. Some 24 full-scale vehicle tests were conducted to provide validation data for the highway-vehicle-object simulation model (HVOSM). All simulated and full-scale tests were conducted at 60 mph (96.5 km/h) and 25-deg (0.4 rad) encroachment angles; therefore, the recommended criteria are based on these operating conditions.

CRITERIA

Recommended design curves are shown for combinations of slopes forming vee, round, trapezoidal, and rounded trapezoidal ditch configurations with widths to 16 ft (4.9 m). A method of evaluating the resultant effect of vehicle accelerations in the longitudinal, lateral, and vertical axes was developed by assigning a severity index to the resultant acceleration and by relating this index to the degree of potential hazard as follows:

$$SI = \sqrt{\left(\frac{ALON}{G_{XL}}\right)^2 + \left(\frac{ALAT}{G_{YL}}\right)^2 + \left(\frac{AVER}{G_{ZL}}\right)^2} \quad (1)$$

where

- SI = severity index;
- ALON = acceleration experienced in longitudinal axis, g;
- ALAT = acceleration experienced in lateral axis, g;
- AVER = acceleration experienced in vertical axis, g;
- G_{XL} = tolerable acceleration in longitudinal (X-axis) direction, g;
- G_{YL} = tolerable acceleration in lateral (Y-axis) direction, g; and
- G_{ZL} = tolerable acceleration in vertical (Z-axis) direction.

Substituting the unrestrained occupant values from Table 1 in Eq. 1 produces

$$SI = \sqrt{\left(\frac{ALON}{7}\right)^2 + \left(\frac{ALAT}{5}\right)^2 + \left(\frac{AVER}{6}\right)^2} \quad (2)$$

A severity index of 1.0 represents a resultant acceleration that may be safely tolerated by an unrestrained occupant. A severity index of 1.6 represents the upper limit of acceleration considered safe for seat belt restraint.

APPLICATION

Desirably, slope combinations would be selected so that unrestrained occupants could be expected to sustain no injury and the vehicle would not incur major damage during traversal. However, site conditions such as restricted right-of-way or other factors beyond the designer's control may dictate the use of slope combinations steeper than desirable. Therefore, design curves are shown for both conditions in Figures 1

Publication of this paper sponsored by Committee on Geometric Design.

Table 1. Tolerable acceleration limits established for ditch traversal study (tentative).

Restraint Condition	Maximum Acceleration (g)		
	Lateral (G_{YL})	Longitudinal (G_{XL})	Vertical (G_{ZL})
Unrestrained occupant	5	7	6
Lap belt restraint	9	12	10
Lap belt and shoulder harness	15	20	17

Figure 1. Tentative design recommendations for vee ditch; round ditch, width <8 ft (2.4 m); trapezoidal ditch, width <4 ft (1.2 m); and rounded trapezoidal ditch, width <4 ft (1.2 m).

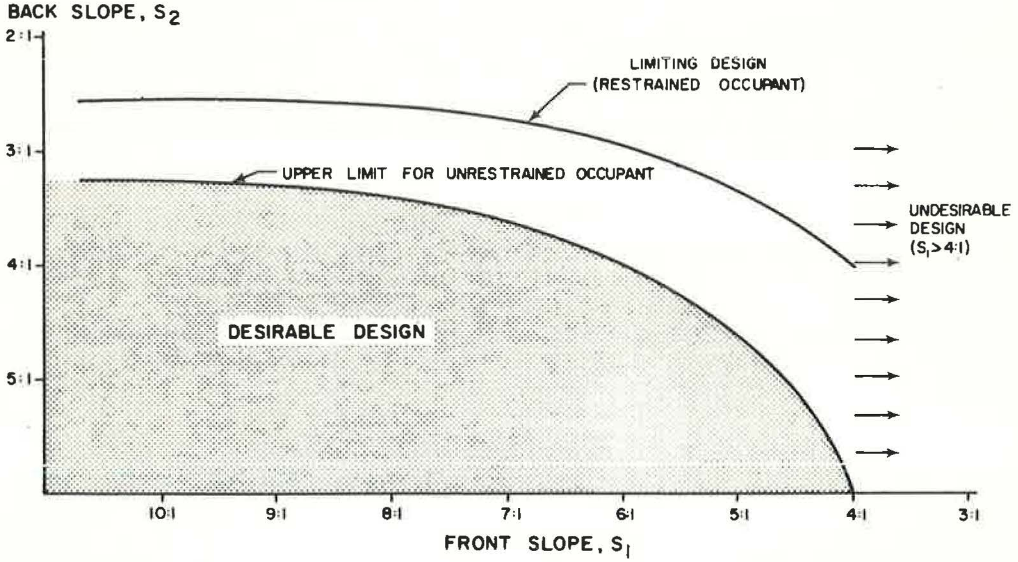


Figure 2. Tentative design recommendations for round ditch, width 8 to 12 ft (2.4 to 3.7 m) and trapezoidal ditch, width 4 to 8 ft (1.2 to 2.4 m).

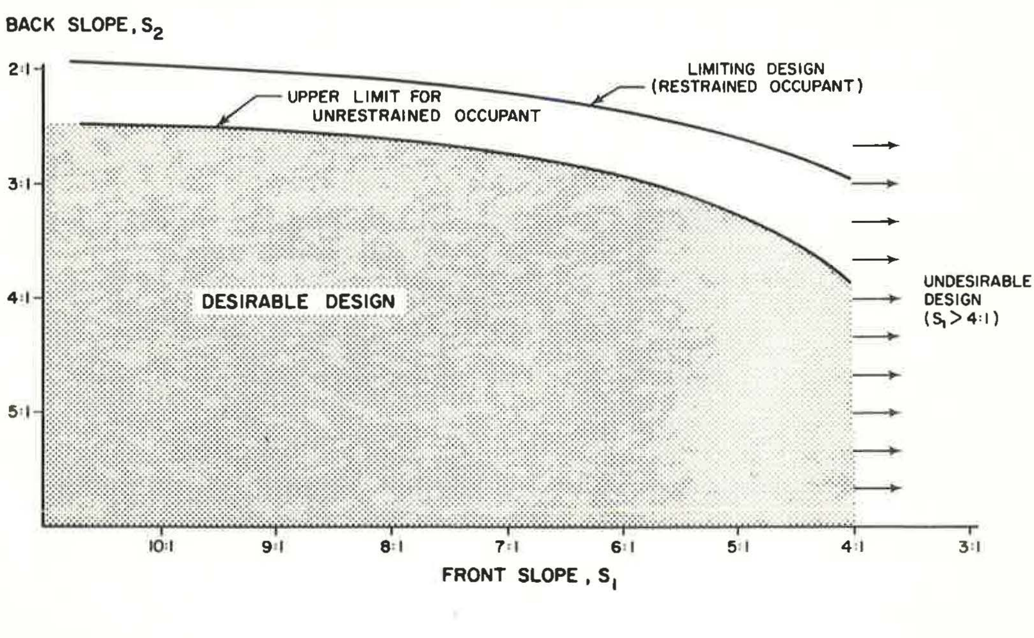
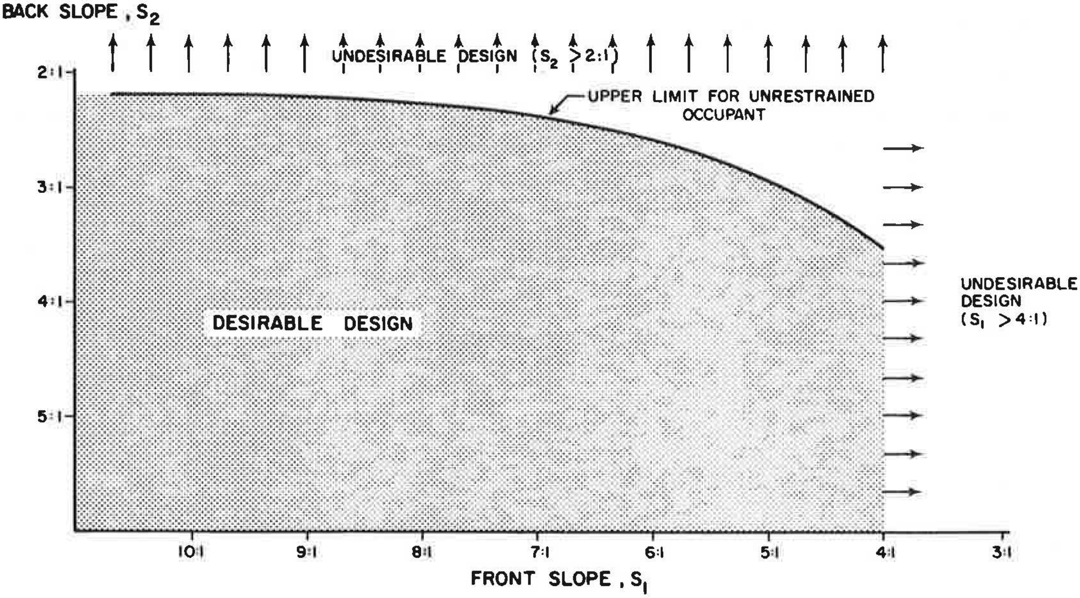


Figure 3. Tentative design recommendations for round ditch, width > 12 ft (3.7 m); trapezoidal ditch, width > 8 ft (2.4 m); and rounded trapezoidal ditch, width > 4 ft (1.2 m).



and 2 for various ditch configurations. Only the desirable design curve is shown in Figure 3 because the limiting design curve would produce slopes of 2:1 or steeper. Earth slopes steeper than 2:1 are difficult to construct and maintain and are therefore not considered practical. The desirable design curve is based on a severity index of 1.0 and a bumper penetration of 4 to 4.5 in. (10.2 to 11.5 cm), whereas the limiting design curve is based on a severity index of 1.6 and bumper penetration of 6.0 in. (15.2 cm).

These curves provide the design engineer with objective criteria for selection of traversable slope combinations and ditch shapes under 60 mph, 25-deg (96.5 km/h, 0.4 rad) encroachment conditions such as might be encountered on high-speed facilities. The design curves are applicable for a ditch location up to 60 ft (18.3 m) from the edge of the roadway.

DISCUSSION OF RESULTS

The vee ditch generally produced g forces that were less severe than those caused by traversing the round or trapezoidal ditches that had widths of 8 ft (2.4 m) or less or traversing the rounded trapezoidal ditch in the 4- to 8-ft (1.2 to 2.4 m) range.

Round ditches generally produced g forces that were more severe than the other three configurations for comparable slope combinations, particularly for steep slope combinations and narrow ditch widths. Little difference in severity can be expected between the shaped ditches with widths in the 16-ft (4.9 m) range.

The trapezoidal ditch configuration offers a cross section that is safer to cross than the others at high speeds, particularly for the steeper slope combinations. The g forces, in general, were lower than those of the vee or rounded ditch. Little safety benefit was realized by rounding the basic trapezoidal cross section to produce the rounded trapezoidal ditch.

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted as part of the National Cooperative Highway Research Program.

REFERENCE

1. Weaver, G. D., and Marquis, E. L. The Relation of Side Slope Design to Highway Safety (Combinations of Slopes). NCHRP Project 20-7, Task Order 2/2, Final Report, TTI Rept. RF626C, Oct. 1973.