National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed and prior to publication of the project report in the regular NCHRP series, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may obtain, on a loan basis, an uncorrected draft copy of the agency's report by request to: NCHRP Program Director, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418

Earth-Berm Vehicle Deflector

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 20-7, Task 3, "Earth-Berm Vehicle Deflector," by T. J. Hirsch, Eugene L. Marquis, and Ray A. Kappel, Texas Transportation Institute, Texas A & M University, College Station, Texas. The study was proposed by the AASHTO Standing Committee on Engineering and Operations.

THE PROBLEM AND THE RESEARCH APPROACH

A number of highway and transportation agencies are using mounds of earth, or earth berms, to restrain or redirect out-of-control vehicles. Most often, the berms have been used around bridge piers, in gore areas of exit ramps, and for burying the ends or beginnings of guardrails. Under certain conditions the berms appear to be more economical to construct than guardrails, and can be aesthetically pleasing. Because of the almost total absence of analytical methods or experimental data, designs of the earth berms that have been used to date have been based almost entirely on engineering judgment and intuition. The study reported herein was a limited attempt to provide factual information that could be of some assistance toward rationalizing the selection of earth-berm configurations as safety elements in the highway system.

A Texas Transportation Institute-modified version of the Highway Vehicle Object Simulation Model (HVOSM), developed at Calspan Corporation, was used to investigate vehicle behavior on earth-berm slopes. (In the study report HVOSM is referred to by its earlier designation of Cornell Aeronautical Laboratories Single Vehicle Accident Simulation (CALSVA). Rigid-body mechanics equations were also used to predict vehicle paths. For the computer simulations, initially assumed operating conditions, all in the free-wheeling mode (no steering), included berm slope angles of 30°, 45°, and 60°, vehicle approach angles of 10°, 17.5°, and 25°, and approach speeds of 30, 45, and 60 mph (48, 72, and 97 kph). The results of these 27 simulations led to additional simulations at slope angles of 35° and 40°, vehicle approach angles of 17.5° and 25°, and an approach speed of 60 mph (97 kph). The results of the computer simulation analysis led to the selection of a berm with a slope of 1.2:1 (40°), a height of 12.5ft (4.10m), and a length of 250 ft (82.0m) for construction and full-scale testing. The slope of 1.2:1 was selected in the belief that this would be about the maximum feasible for acceptable vehicle impact behavior (which full-scale testing later showed to be too steep).

Two criteria were used to judge the capability of the earth-berm slopes to safely restrain or redirect traversing vehicles: vehicle rollover, and vehicle accelerations tolerable to humans. The following were established as maximum tolerable levels of acceleration based on the work of others (Hyde, A.S., "Biodynamics and Crashworthiness of Vehicle Structures," Wyle Laboratories Research Staff Report WR 68-3, Volume III of IV, March 1968), and to some extent on the researchers' best judgment:

	Maximum Acceleration (G's)		
Restraint	Lateral	Longitudinal	Vertical
Unrestrained occupant	5	7	6
Lap-belt restraint	9	12	10
Lap-belt and shoulder restraint	15	20	17

Because of the steepness of the slope that was selected for the earth berm, thorough compaction could not be achieved at the slope surface. This resulted in a general looseness that undoubtedly influenced the results of the full-scale tests.

Five full-scale tests were conducted on the 1.2:1 slope using a 1963 Ford Galaxie very similar to the vehicle simulated in the computer program. The tests were conducted using an approach angle of 15° and speeds of approximately 20, 40 (two tests), 43, and 53 mph (32, 64, 69, and 85 kph). The vehicle was appropriately instrumented to measure the lateral, longitudinal, and vertical accelerations taking place during traversal of the berm.

When it was noted that the front wheels of the vehicle turned toward the slope on impact, additional computer simulations were run with a programed steering angle of 22 1/2° directed up the slope to see whether correlations between computer results and the results of the full-scale tests could be improved.

FINDINGS

The peak and average accelerations (G's) that occurred when the full-scale vehicle impacted the 1.2:1 earth-berm slope were in good agreement with those predicted by the HVOSM computer simulation of a free-wheeling vehicle. The lengths of the berm traversal were also in good agreement with those predicted.

The vertical height of vehicle climb was about twice that which was predicted by computer simulation; furthermore, two unpredicted rollovers took place. The rollovers occurred in one of the two 40-mph (64 kph) tests, and in the 53-mph (85 kph) test. Programing a steering angle of 22 1/2° up the slope at the point of impact in the computer simulation (as observed in the full-scale tests) improved the correlation between the computer and the full-scale test results.

Softness of the slope surface resulting from construction difficulties due to slope steepness is believed to have had an adverse effect on the correlations between the computer simulations and the full-scale test results.

Relatively simple rigid-body equations that neglected friction between the vehicle and the slope surface and assumed the vehicle mass to be concentrated at a point (analogous to rolling a rigid ball up an inclined plane) showed promise as a convenient means for estimating the height of vehicle climb and the length of slope traversed.

CONCLUSION AND RECOMMENDATIONS

From the limited amount of work that was conducted, it could be concluded only that very steep slopes, at least in the order of 1.2:1 and steeper, are probably not appropriate for earth berms to be constructed as highway safety elements. Nevertheless, the research approach that was used seemed to be sufficiently promising to support a recommendation that it be applied in further studies to evaluate more fully the effectiveness of earth berms in restraining or redirecting vehicles in hazardous areas.

NOTE:—

The research with which this report is concerned was completed in February 1971. Subsequent testing and research regarding vehicle behavior on earth slopes suggests that the height and width requirements for an earth berm to be effective as a vehicle deflector are probably of a magnitude discouraging to their use, except in unusual circumstances. For information on the additional research, the reader is referred to:

1. Weaver, Graeme D., Marquis, Eugene L., and Olson, Robert M., "Selection of Safe Roadside Cross Section." NCHRP Report 158 (1975).

2. Ross, H.E., and Post, E.R., "Comparisons of Full-Scale Embankment Tests with Computer Simulations - Volume One: Test Results and Comparisons. Res. Rep. 140-7, Texas Transportation Institute, for Texas Highway Dept. (Dec. 1972).

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