THE PROBLEM OF HEAVY VERSUS SMALL VEHICLES AND ROADSIDE HARDWARE

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After many years of nearly imperceptible change in the composition of highway traffic, we are experiencing a rapid evolution. Passenger sedans are becoming smaller, while bus and truck traffic is increasing.

Most current roadside hardware (such as guardrails, median barriers, bridge railings, crash cushions, and breakaway sign supports) was developed some 10-20 years ago, when gasoline prices were low and cars were larger. Nearly all traffic, as well as roadside collision injuries and fatalities, involved passenger sedans in the range of 2000-4500 lb. Accordingly, roadside hardware was essentially designed to function with this range of vehicle size. Since severe test conditions (i.e., a 4500-lb vehicle at 60 mph and a 25° angle) are used, the resulting hardware generally exceeds the normal performance range for passenger sedans and will accommodate vehicles heavier than 4500 lb when the impact conditions are modest. Fortunately, bus and truck traffic has generally been light, and the modest impact conditions are seldom exceeded.

There is growing concern, supported by preliminary crash tests, that current roadside hardware will not function properly with the vehicles that weigh less than 2000 lb. Moreover, as a result of the increase in bus and truck traffic, there is further concern that current roadside hardware will prove to be inadequate for heavy vehicles under a growing number of severe collision-impact conditions. These factors could easily lead to higher rates of roadside collision injuries and fatalities.

At first glance, it might seem surprising that vehicles that weight less than 2000 lb should be a problem. There are, however, several problems:

1. Decreases in vehicle mass are accompanied by increases in the acceleration, momentum, or velocity change induced in the car during impact with roadside objects, such as breakaway supports, crash cushions, or longitudinal barriers. The occupants are therefore subjected to a greater degree of risk.
2. The smaller wheel tracks and base lengths reduce the dynamic stability of the vehicle during shoulder slope encroachments and barrier redirection. More rollovers are foreseen.
3. Because of smaller wheel diameter, the front wheels can wedge under roadside, median, and bridge barriers of standard height, causing abrupt vehicle snagging and spin-out.
4. The mass moments of inertia are less, making the vehicle more prone to upset or to violent reactions during off-center impacts with breakaway supports, barrier terminals, or crash cushions.

The test driver of this full-sized automobile escaped injury after collision with this breakaway sign, but the operator of a smaller car might not be so lucky.

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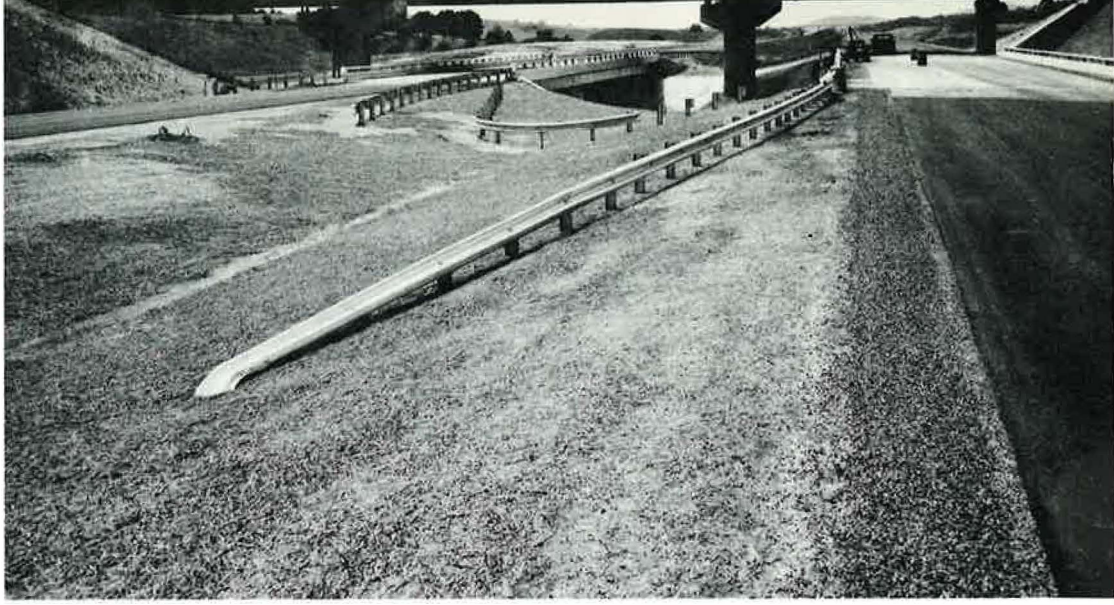

Smaller wheel diameter, lighter weight, and reduced wheel track and wheel base of smaller cars can affect their behavior on impact with steel guardrails designed for larger vehicles.

5. Since the ground clearance of the small car is generally less than the 6 in of exposed concrete base allowed for current breakaway supports, small cars will readily snag on the rigid concrete foundations.

The heavy vehicle poses a different set of problems to the roadside hardware developer. At impact, the heavy vehicle may possess kinetic energy that is 40 times greater than that of a passenger sedan. Thus, longitudinal barriers must be substantially stronger in order to contain and redirect the heavy vehicle. The longitudinal barrier must also be higher to properly interact with the larger vehicle and its relatively high center of mass. Structural and foundation requirements of the barrier to sustain the intense dynamic force applied a considerable distance above grade are technically feasible but are costly. Moreover, a special softening feature or staging may be required in the stiff structure in order to safely accommodate the small car impacts, which are likely to be more numerous. Bridge deck strength may be the limiting factor in determining the maximum size of vehicles that can be redirected by a bridge railing. Excluding upgrade escape lanes and gravel beds, crash cushions for heavy vehicles, especially tractor-trailer rigs, do not appear feasible. This is because the tie-down for cargo, which can represent a major portion of the heavy vehicle's mass, and tractor-trailer king pins are generally designed for a cargo load shift of 1-2 *g*. Hence, a crash cushion would be designed to impose a maximum force of 1 *g* on the smallest heavy vehicle, and this would translate into a fractional *g*-force for the heavier vehicles. Irrespective of the energy-dissipating mechanism of a crash cushion, the device for a 55-mph impact would be at least 100 ft long, an unacceptable size for most potential sites. Additional staging would also be required to accommodate passenger sedan impacts. Breakaway supports (such as luminaire and sign supports) do not appear to present a hazard to the heavy vehicle, with the possible exception of the missile potential of elements detached during the impact.

In the face of declining highway construction and maintenance funds, the outlook for upgrading existing roadside facilities to accommodate the new small cars and the increasing number of large vehicles is not bright. We must "scratch where it itches" and allocate limited resources where the greatest benefits will accrue. A possible strategy could include the following tasks:

1. Evaluate all existing operational roadside hardware for safety performance in relation to passenger sedans that weigh less than 2000 lb. In addition, establish upper strength capabilities of operational roadside hardware by means of heavy-vehicle crash tests.
2. Develop inexpensive modifications that will upgrade safety performance of existing roadside hardware to accommodate the sedan that weighs less than 2000 lb.
3. Develop inexpensive modifications that will increase existing hardware strength to handle a larger range of heavy vehicles.
4. Develop new roadside hardware especially designed for the small car and for heavy vehicles.
5. Develop new warranting criteria for roadside hardware that are based on degree of risk and modern benefit-cost technology.
6. Selectively upgrade or install improved roadside hardware as funds become available.

Task 1 is necessary in order to reveal the extent of the problem. There may be operational hardware that requires only minimum adjustment, while other hardware may be functionally inadequate.

Tasks 2 and 3 recognize the trend in which an increasing percentage of highway funds is being allocated to maintenance activities and spot improvements, while lesser amounts are being spent for new construction. Moreover, task 2 is considered more important than task 3 because upgrading costs will probably be less and potential benefits will probably be greater, because of numerous small-car collisions. On the other hand, effort on task 3 is needed because there is an increasing number of sites in the country where the heavy-vehicle population warrants a higher level of roadside safety protection.

Task 4 is directed to new hardware that will accom-

modate the full range of vehicle sizes. As in task 2, the principal emphasis should be on the passenger sedan vehicles, especially those that weigh less than 2000 lb, due to the more numerous sedan injury and fatal roadside collisions; however, hardware that will perform with the heavy vehicle as well as the small sedan is needed for a number of especially hazardous sites.

Effort on task 5 is needed to identify the best uses of dwindling highway funds in reducing injuries and fatalities. Finally, task 6 implements findings from tasks 1 through 4 with methodology from task 5.

Some work is being performed in each of the six tasks by the Federal Highway Administration and several state highway agencies. However, it will be several years before a complete array of systems is available, and then several more years before a significant number of installations are in place. Possibly, improvements in crashworthiness of the small cars and in vehicle-occupant protection systems may offset, during this interim period, any inadequate performance of present roadside hardware.

Breakaway sign bases are designed to operate under impact from a vehicle that weighs more than 2000 lb; they may cause injury to the occupant of today's small car.

Crash barriers can be modified to attenuate the progress of a lighter vehicle, but the modification reduces their protection for larger and heavier vehicles.